February 1955

NUCLEONICS

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MEN AT WORK . . .

First meeting (above) of seven-nation UN advisory committee set up to plan a nuclear conference, heralds worldwide benefits from peaceful atom

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. . . ATOMS AT WORK

Another first (right), sea trials of nuclear-propelled *Nautilus*, has far-reaching implications for nonmilitary use of nuclear power beyond naval use

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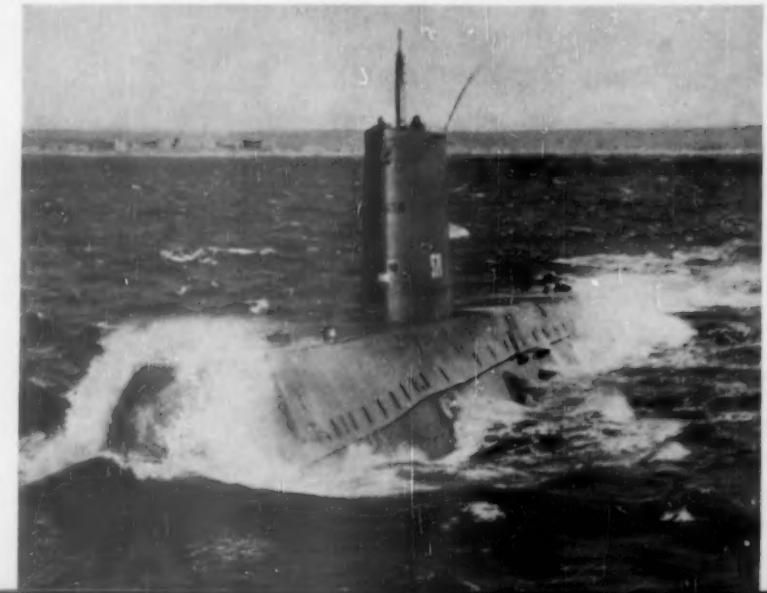

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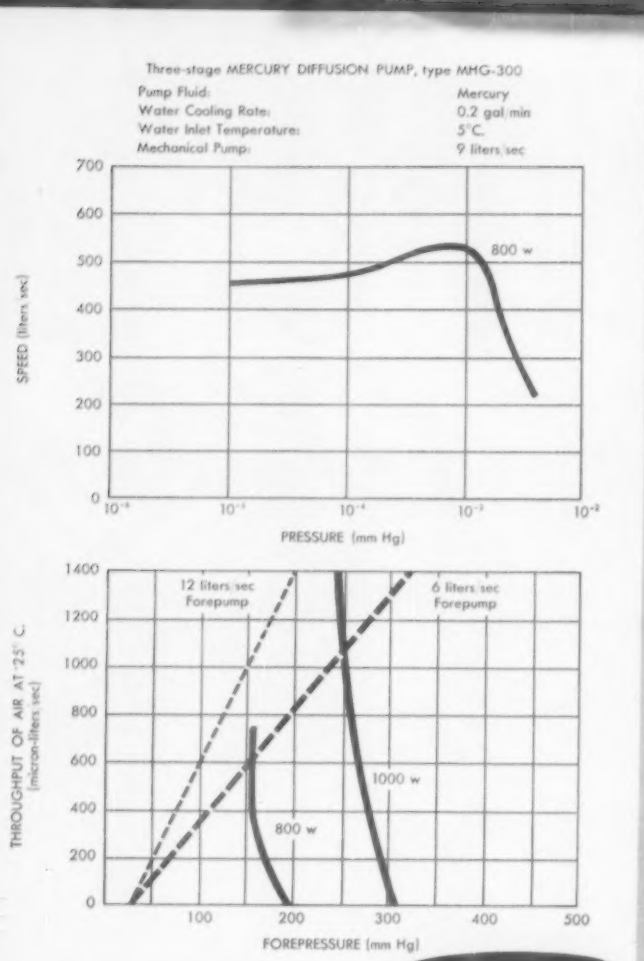

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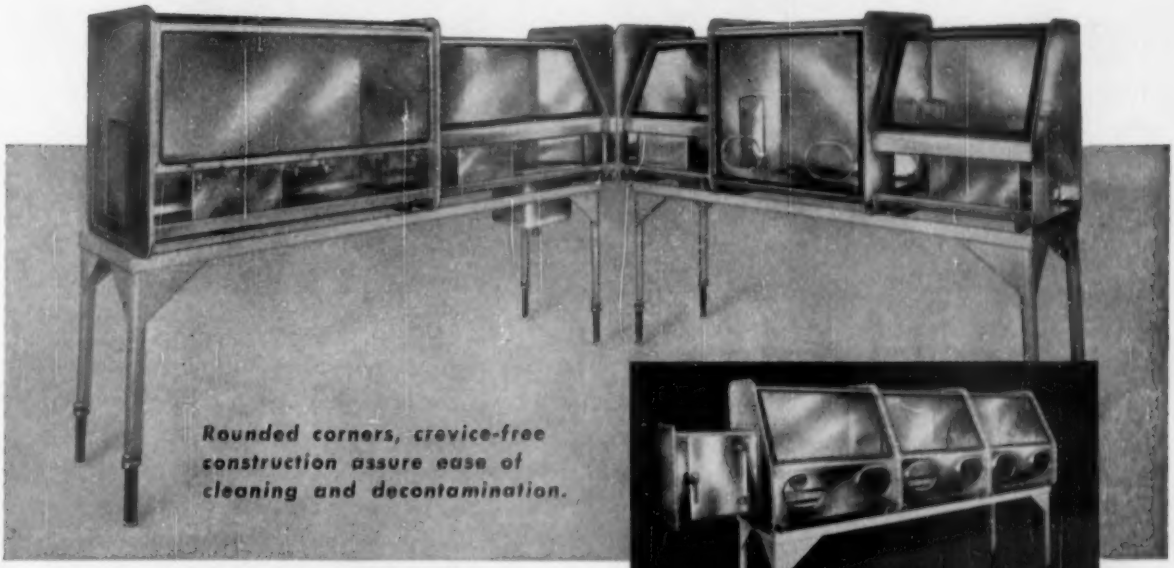

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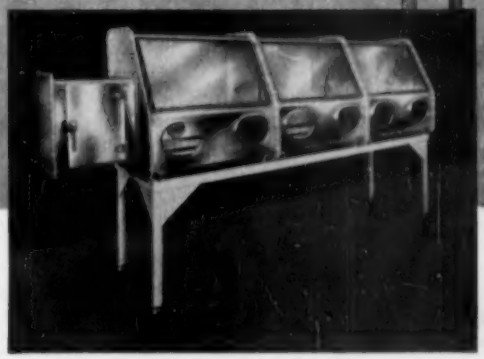

SEND FOR TECHNICAL BULLETIN A-4 providing additional information about this interchangeable dry box system.

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ROUNDUP

OF KEY DEVELOPMENTS IN ATOMIC ENERGY

LATE NEWS AND COMMENTARY

Industrial Reactor If industry doesn't take AEC up on suggestion that a private group build a test reactor (NU, Jan. '55, p. 9), AEC may have to do so to meet its own needs. Phillips Petroleum Co., operator of AEC's materials testing reactor in Idaho, has already designed an "engineering test reactor" (ETR) for AEC.

•

Insurance Problem The Joint Committee on Atomic Energy will take a hard look at whether statement in law that Federal government will be held "harmless from any damages resulting from the use or possession of special nuclear material" must be changed to facilitate assistance to industry in meeting nuclear power plant insurance needs. At present, some kind of Federal reinsurance plan seems a must. If this is done, expect AEC policing of plant safety features to be quite stringent.

•

AEC Reports to Congress Among other things, AEC's 17th Semiannual Report to Congress:

¶Confirms earlier reports (NU, Aug. '54, p. 6) that its Idaho boiling water reactor "ran away" last summer during tests of the system in which "the power was allowed to rise well over a million kilowatts in 0.1 sec." A second such reactor, operating at a higher power (6,000 kw of heat) and pressure (300 psi), was then built at the same site.

¶Details progress in its breeder program. A third core, of plutonium, is about to replace EBR-1's second uranium core. A half-scale working model of the much larger EBR-2 will start running at Argonne next month.

¶Reveals construction of a $91,550 gamma radiation facility at Argonne to be used primarily by the Army for food preservation studies, but also to be available to Argonne researchers and industrial concerns.

¶Shows that radiochemical processing plants cost about 12 times as much to build as similar plants processing nonradioactive materials. According to AEC, the total annual operating cost of a radiochemical plant may be almost three times that of a conventional plant.

•

AMF Reactor American Machine & Foundry Co. has invited industrial concerns to join it in supporting the first industry-owned research reactor. AMF is planning to build a $1- to $1½-million, 100–1,000-kw swimming pool unit on a 250-acre site near New York City. AMF also will build similar units for Battelle Institute.

•

Compulsory Patents Rep. W. Sterling Cole (R., N. Y.), chairman of the Joint Committee in the 83rd Congress, fulfilled a promise he made when the new law was passed last year by introducing last month a bill (HR-1777) that states "that sections 153 and 154 of the Atomic Energy Act of 1954 are hereby repealed." These are the compulsory patent licensing sections.

•

Reactor Training Although not publicized, a small number of American industrial engineers will be able to attend the reactor school at Argonne National Laboratory set up primarily for foreigners. Aimed at beginners, the comprehensive, 7-month, unclassified course will start next month. A second course will start in October.

•

UN Meeting Contrary to earlier expectations, the United Nations atomic energy conference, to be held in Geneva Aug. 8–20, will be open to the public to the extent of availability of space in the 1,000-seat auditorium. President of the conference

will be India's chief nuclear scientist, H. J. Bhabha. Secretary general will be Walter G. Whitman of MIT, a member of the AEC general advisory committee.

Although there will be considerable emphasis on radioisotopes and basic nuclear science, greatest interest will be in nuclear power. The "have" nations will undoubtedly vie with one another for plaudits on who is most advanced in the power field. Undoubtedly, the date for committee review of papers will be set late to prevent one nation from "cribbing" from another, as some anticipate, but more important, to prevent some from determining how far they'll go on releasing information according to what they see in the papers of other nations.

•

Congressional Hearings

With AEC testifying, the first two days of biennial hearings on the state of the atomic industry that Sec. 202 of the new law requires the Joint Committee on Atomic Energy to hold produced the following developments:

¶With Sen. Gore (D., Tenn.) taking the lead, much time was taken up with matters presumably unintended for discussion at these hearings. Until the Dixon-Yates power issue is resolved, AEC will be split, and AEC Chairman Strauss will be under attack by the JCAE majority.

¶The split between Commissioners Strauss and Murray was aired further. Strauss was attacked by JCAE Chairman Anderson (D., N. M.) for not having told either the JCAE or the other commissioners about General Manager Nichols' talk with Strauss in Sept. '54 about Nichols' impending resignation. Anderson feels the general managership is so important that Strauss should have kept the JCAE and the commissioners "fully informed."

¶Nichols' resignation (submitted Jan. 17) after 14 months as AEC's third general manager will be effective May 1. With a reputation as a hard-boiled executive, Nichols instituted many organizational changes in AEC.

¶Drafts of licensing regulations required by the new law will first be ready in March. They will then be: (a) examined by industry committees, (b) acted upon by AEC, and (c) published in the Federal Register as proposed regulations.

¶Although the terms were said to be not generally applicable to industry, AEC has issued its first license—to the Dept. of Defense for a reactor using U-235 at Dugway Proving Grounds.

¶AEC expects 100 new industrial participation agreements will be signed in '55 under three plans: (a) access agreements—for 1-year period for access to confidential data by companies that want to evaluate their place in the atomic industry; (b) existing study-type agreements—for access to secret data; and (c) commercial agreements—for access to confidential and/or secret data for those working commercially in atomic energy.

¶Sen. Anderson was highly critical of this "agreement" program. He feels anyone who can qualify for security clearance should be given full access without any strings attached. He feels a company should not have to justify a request for clearance, nor should it have any obligations to AEC once it has been cleared, including such things as present information reporting requirements.

¶By implication AEC was criticized for instituting its present feed materials plant expansion by contract rather than by license. Although at least one company was apparently willing to undertake the job under a license, Gen. Mgr. Nichols felt there wasn't enough time and that AEC's needs were too fluid.

¶AEC says it will make nuclear fuel available to licensees for period of their license.

¶A reactor concept using hydrocarbons as moderator and coolant "is perhaps the most advanced and may soon justify assembly of a reactor experiment," says AEC.

¶April 1 deadline for industrial submission of "demonstration reactor" proposals was criticized by JCAE. AEC expects at least four "good" proposals by then. $75-million has been slated for this program.

AEC Announces Industry-Assistance Plan, Fuel Prices

An Atomic Energy Commission plan to implement the advance of nuclear power technology was generally hailed by industry last month, but a schedule of prices and payments for nuclear fuels evoked a mixed reaction. Several companies already active in nuclear power study groups told NUCLEONICS they either planned or "hoped" to submit proposals under the power demonstration reactor program to AEC by the April 1 deadline. Others, confident that the response would be sufficient for AEC to extend the program, expect to submit proposals later.

This new program provides a three-point plan under which AEC will cooperate with industry in power-reactor development. First, AEC may waive established charges for lease of source and special nuclear materials—nuclear fuel. Loans without charge can be for as long as seven years from July 1. But licensees will have to pay for materials consumed and for AEC-performed services such as processing of spent fuel, even though AEC isn't required to charge for them under section 104 of the law.

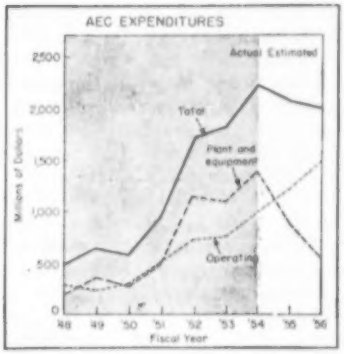
Second, AEC would not charge for certain mutually agreed upon research and development work performed in its laboratories for the licensee.

Third, AEC would contract, under section 31a ("research assistance") of the law, for technical and economic information resulting from power-reactor development, construction and operation. Payment, fixed in advance, could be used for development, fabrication, and experimental operation. Generally, the data gained would be disseminated as widely as possible by AEC. But provisions for patent rights could be negotiated when the contract was made, and distribution of information would then be restricted. It is not clear whether further negotiations would be needed at the time of a patentable discovery.

AEC's attitude towards patents is that work performed by the contractor would probably be patentable, while work AEC does for him in its facilities would not. Section 152 of the atomic energy law provides that AEC must waive its rights before a private patent can be obtained on a development made under any "relationship" with AEC.

The proposed "payment for data" and the free-fuel provisions are apparently designed to circumvent section 169 of the new law, which prohibits subsidy of licensees by AEC. This was necessary as an alternative to the "reactor of the year" plan, which was the genesis of the present proposal. Under the "reactor of the year" idea, it was suggested that AEC might subsidize an industrial project to the extent of the difference between the cost of a nuclear power plant and that of a conventional plant. Presumably the extent of support under the present plan will effectively be the same.

However, different from the Duquesne PWR project, the AEC contribution will be a fixed sum. Another difference from the PWR setup is that the company would own the total plant (in PWR, AEC will own the reactor, Duquesne the conventional power generation equipment).



BUDGET ESTIMATE submitted to Congress by President Eisenhower shows Atomic Energy Commission operating costs increasing sharply while plant and equipment expense drops off as present expansion program is completed

It is expected that AEC will make payments to contractors in installments, but this will be subject to contract negotiation. It's understood that funds for the program are already in AEC's budget for the fiscal year starting July 1.

How AEC Will Choose

To evaluate the proposals it receives, AEC has set up five criteria: (a) probable contribution toward achieving economically competitive

UNITED NATIONS ADVISORY COMMITTEE meets around conference table in New York to plan international nuclear energy conference. (See story, p. 9.) From left at table are H. Bhabha (India), B. Goldschmidt (France), W. B. Lewis (Canada), J. Coste Ribeiro (Brazil), G. Randers (UN), UN Secretary General Hammarskjold, Ralph Bunche (UN), I. I. Rabi (United States), J. V. Dunworth (United Kingdom), and D. V. Skobeltsyn (Union of Soviet Socialist Republics)

ROUNDUP

power; (b) cost to AEC in funds and materials; (c) risk assumed by the maker of the proposal; (d) maker's competence and responsibility; and (e) assurances against abandonment of the project. The last two bear directly on the fact that, to be acceptable, a proposal must be made by a person or firm who can qualify for a license under section 104 of the law. But AEC stresses that the probable contribution of a proposal will be the primary basis for determining its acceptability. That is, within the limits of funds and materials, AEC will not discriminate against a more expensive project, but will actually favor it if it promises greater advance of the art.

Prices in L-Category

Industry's reaction to the price and payment schedule was unanimous on only two points—all welcome it as something definite on which to hang cost estimates that up to now have been largely guesswork, and all were glad that, although classified, the prices were only "confidential" and thus in the gray area where industry could get at them. But Senator Clinton P. Anderson, chairman of the Joint Committee on Atomic Energy, apparently is dissatisfied that they are classified at all—he didn't want the schedule in his office. (Sources close to Anderson say this merely indicates his attitude towards classification in general.)

As for the schedule itself, the actual figures for charges AEC will make for natural uranium, thorium, heavy water, uranium-235, uranium-233, or plutonium and payments for uranium-233 and plutonium were not released. (The last three items for which AEC charges can only be leased by licensees and not sold to them.) But AEC says that the prices and payments are on a sliding scale, with value varying with enrichment and quality of plutonium. AEC also says that the prices are based on "value per recycle in a power reactor." One interpretation of this is that the sliding scale based on fuel quality is so arranged that the difference between original price and payment for material in used fuel would equate to the cost of treatment to reclaim and possibly re-enrich the material.

AEC also makes the point that, even though prices have been established for fuel-value material (plutonium), none will be available at these prices until some is acquired from licensees.

Reaction to the price and payment schedule, which was previewed by some industrial contractors a month before it was announced, was mixed. One eminent authority called them very, very low, told NUCLEONICS that industry "couldn't afford to operate a reactor even if they got the reactor for nothing." But others looked at them as long-range prices, and thought they would be an incentive to industry to produce more efficient plants and to think realistically. One comment was that AEC kept prices low to favor power reactors over production facilities.

While AEC established the principle, in conjunction with the price list, that industry would be charged

Washington Report

Even before Atomic Energy Commission members gave final approval to detailed limits for L-clearance information, AEC's technical information staff was well along in setting up a program to disseminate it. With tens of thousands of classified reports in AEC files, the staff didn't want to delay selecting those that would be useful to industry until the last minute—about half the reports must be reviewed for the lower classification.

Tentatively, the staff feels that about one-half of these documents will be of interest to industry generally, and that only about one-eighth of the total can be considered significant major studies needed in the gray-area information program. Further, they have found that about 45 subject areas cover all the reports, with an average of about 100 useful reports in each area. The assumption is that most participants in the gray-area program will be satisfied with a selected few reports containing the most important information on a particular subject; only a few industrial participants will want to review all literature in a given subject area.

Working on this base, the staff is well along on a plan to reproduce the reports they think will be in demand, at reasonable prices. They are planning full-size reprints of selected "packages," consisting of a reactor handbook, abstracts of classified and declassified reports, and chosen gray-area reports. These will be available at prices that will recover the actual costs to the Government. Also planned, for those who want to see all, are 3-by-5-inch microcards, priced at a nominal figure, which can be read easily through a $250 reproducer. The technical information staff estimates that three-fourths of its gray-area customer load will be microcard requests.

Rounding out the gray-area information program will be a journal of abstracts that will serve as a comprehensive catalog. This will be based on an abstract journal of classified reports that has been published twice a month since 1947; items still classified will be blocked out. Technical staff personnel will also be available for consultation on a participant's needs.

Even though it now knows the limits of the gray area, the technical information staff still has to wait for some indication of industrial interest and the number of licenses of all types that will be issued under the new law before it can plan the actual mechanics of its printing program.

If the gray-area program gets large enough, regional distribution centers like the 42 existing depositories for declassified data may be set up. But a big problem in any such expansion program would be lack of storage space for classified reports.

the full cost of AEC services such as fuel reprocessing, one industrialist pointed out that this made the price list incomplete because actual charges aren't specified.

AEC also guaranteed its payment schedule for seven years beginning July 1. This may in part explain the low scale. But both prices and payments will be changed if there are substantial changes in the Bureau of Labor Statistics' wholesale prices index, excluding farm products and processed foods.

More rapid change will occur if those who think the schedule too low have their way. One idea is for industry to wait, then hit hard at AEC to raise its payments.

Another contentious point is the start of the guaranteed schedule. It's pointed out that no industrial power reactor will be operating by July, and that the guarantee doesn't hold, therefore, for seven years of reactor operation. And while AEC interprets the law as allowing it to extend the guarantee period, industry has no promise this will be done.

In spite of these comments, the general industry attitude towards the price list was one of approval, with many indications that companies queried could now move faster towards their goal of nuclear power.

UN Advisory Committee Meets, Plans Conference

After first meeting on January 17, the advisory committee for the international conference sponsored by the United Nations moved rapidly towards completing plans for the meeting. UN officials had set January as the target date for committee recommendations (NU, Jan. '55, p. 79). The conference is scheduled for August in Geneva, Switzerland.

Participating in the committee meetings were representatives of seven nations and Gunnar Randers, who is serving as Secretary General Dag Hammarskjold's special consultant for the conference. (See pictures, page 7 and front cover.)

Russia Offers Data

Just before the committee met, Russia announced that it would make available data on its 5,000-kw nuclear power plant for presentation at the international conference. Later, it announced that it was setting up an atomic pool with China, Poland, Czechoslovakia, Ru-

About the Industry

Make first feed-materials construction awards. Cost-plus-fixed-fee contracts are being awarded by AEC for expanding uranium processing plants (NU, Nov. '54, p. 118), but AEC "contemplates" that much of the work will be subcontracted on a lump-sum bid basis. So far, contracts for the $39.8-million expansion at St. Louis and Weldon Springs, Mo., have been awarded jointly to Fruin-Colnon Contracting of St. Louis and Utah Construction of San Francisco; Maxon Construction of Dayton, O., was selected for the $20.1-million Fernald expansion.

Westinghouse employment up. Backing up president Gwilym Price's statement that "the horizons are unlimited for atomic power" is the growth of Westinghouse Electric's atomic power division to more than 2,000 employees during 1954.

Investment firm hires nuclear guides. To keep abreast of atomic development, a New York investment firm, National Securities & Research, has retained Nuclear Consultants, Inc., New York. Besides analyzing the scientific programs of companies in which National has invested, Nuclear Consultants will report periodically on developments in both atomic energy and electronics.

Oil industry gets special service. With oil firms the largest industrial users of radioisotopes, Tracerlab has opened a laboratory at 2419 South Blvd., Houston, Texas, solely for supplying radioactive material to them. L. F. Tischler heads the new unit, which is prepared to make shipments on 24-hr notice.

Oil producers use radioactive tracers to evaluate and control water flooding of oil fields for secondary recovery, to test oil-well casing cement for leaks, to locate oil or gas-pad level in salt domes and thus control brine recovery, to tag drilling mud to determine permeability of formation being drilled, and to tag cement to locate its level around a well casing.

Study group adds nine firms. Atomic Power Development Associates, originally the Dow-Detroit Edison power study, now numbers 34 firms, including utilities representing 37% of investor-owned U. S. electric generating capacity. New utilities are: Boston Edison; Central Hudson Gas & Electric; Connecticut Light & Power; Long Island Lighting; New England Gas & Electric Assoc.; New York State Electric & Gas; and Wisconsin Power & Light. Two engineering firms—Commonwealth Associates and Jackson & Moreland—also have joined the group.

Institute of Nuclear Medicine gets funds. General Dynamics Corp. has provided funds to get the new Institute of Nuclear Medicine started at the Lovelace Foundation for Medical Education and Research, Albuquerque, N. M. Other industrial firms are expected to underwrite continuing research on medical uses of radiation.

Industrial applications firm formed. Charles H. Lutz has resigned from Designers for Industry to form his own consulting firm, Atomic Energy for Industry, Inc., 344 Hanna Building, Cleveland, O. The new firm will specialize in industrial applications of radioactivity.

ROUNDUP

mania, and East Germany. Under this pool, Russia would provide member nations with nuclear reactors and equipment; Russia will get uranium ore in return.

Bhabha Tells Indian Needs

India's representative, Dr. Homi Bhabha, asked what kind of assistance India most requires, told NUCLEONICS "know-how and very little else." He added, "In course of time, we shall get this know-how through our own efforts, but given it now, we could speed up our atomic development."

Bhabha listed materials for reactor construction, methods of producing nuclear power, chemical processes and engineering of associated chemical plants as subjects in which India is vitally interested. He believes the international conference should discuss different types of reactors, and, above all, encourage a free exchange of views on the basic approach to nuclear power as well as make a careful assessment of the economics involved.

"Each nation," he said, "should be provided with know-how so that it can make its own contribution to this vital new industry through setting up of relevant plants or reactors on its own soil." India has already started on a $20-million plant to produce 5 to 6 tons of heavy water a year in conjunction with fertilizer manufacture, has one of two uranium and thorium extraction plants already in operation. Plans for a beryllium-producing plant are being considered.

Other Nations Interested

While the UN committee is setting up the international conference, smaller nations are expressing increasing interest in nuclear development. Turkey's Premier Menderes told Morehead Patterson, special ambassador charged with implementing the Eisenhower program, that his country was eager to benefit from peaceful applications of atomic energy, that Turkey was planning to ask for U. S. nuclear material.

In Austria, the government set up a nine-member advisory atomic energy commission last month to discuss the advisability of setting up a reactor and sending Austrians abroad to participate in nuclear training programs.

UN Agencies Coordinate

UN specialized agencies that will be represented at the conference are already taking steps to coordinate their atomic energy activities. The UN Educational, Scientific and Cultural Organization (UNESCO) is studying "measures of international scope to facilitate the use of radioisotopes in research and industry" so that it can cooperate in UN projects. The World Health Organization is gathering from its member governments copies of regulations protecting atomic energy workers, and is planning to explore use of atomic energy in medicine, biology, and public health.

To assess effects of atomic explosions on weather, the World Meteorological Organization is assembling data from all nations.

ANS Incorporates, Pushes Plans for First Meeting

The American Nuclear Society, having formally incorporated in New York State last month, is developing the program for its first annual meeting at Pennsylvania State University, June 27–29. Officers and directors will be elected by mail ballot between April 1 and June 1 from a slate being prepared by a committee headed by C. Rogers McCullough, Monsanto Chemical Co. The new officials will be installed at the meeting.

James A. Lane of Oak Ridge National Laboratory, is chairman of the technical program committee. Papers are expected on fast-reactor technology, experimental nuclear techniques, radiation effects on biological and physical systems, sources and economics of reactor materials, problems in reactor fuels, reactor safety considerations, applications

Technical Advances

Gaseous scintillators. Light from gaseous atoms excited by fast charged particles provides a new means of detecting nuclear radiations. The new technique complements the classical use of ionization as a detector and uses the technology built up for solid and liquid scintillators. C. M. Huddleston (Argonne National Laboratory) has detected ultraviolet light from argon gas excited by the passage of an alpha particle. He uses a film of 2.6% tetraphenylbutadiene in polystyrene to shift the ultraviolet light into the visible region for detection with a photomultiplier.

Counter efficiency is essentially 100%; energy resolution is 10% for 5-Mev alphas. Although pulse height is only 2% of that obtained with a NaI crystal, it is well above noise and gamma-ray pulse heights and can be improved further. L. F. Wouters, at Livermore, has applied this new detection principle to a fission counter getting 10^{-8}-sec pulses 16× accompanying alpha background.

Chemical dosimetry and ion density. It has long been expected that the radiation effects utilized in liquid chemical dosimeters would vary with ionization density. This has now been shown to be the case quantitatively: calibration of ferric-ferrous dosimeters is smaller for radiations producing higher linear ionization densities.

Norwegian researchers L. Ehrenberg and E. Saeland (Joint Establishment for Nuclear Energy Research) have measured the following yields (G values expressed as $Fe^{3+}/100$ ev): fission fragments, 3.0 ± 0.9; B^{10} $(n,\alpha)Li^7$ recoils, 4.0 ± 0.4; protons from $N^{14}(n,p)C^{14}$, 7 ± 1; $Li^6(n,\alpha)H^3$, 5.4 ± 0.3 (from which 6.5 ± 0.7 is calculated for H^3); 175-kev X-rays, 17.4 ± 0.8; 160-Mev protons, 16.5 ± 1. Similar effects occur in ceric-cerous dosimetry, but the variation with ionization density is not the same. Thus G_{Fe}/G_{Ce} decreases from 4.7 for lightly ionizing gamma rays to 1.6 for densely ionizing alpha rays.

and technology of accelerators, and the role of chemical processing in nuclear power economics.

Two Nuclear Exhibits Planned for '55

Firmly indicating that nuclear energy is itself an industry, two organizations have announced plans for trade shows this year. The Atomic Industrial Forum is planning its first Annual Trade Fair of the Atomic Industry to coincide with its annual fall meeting in Washington, D. C., Sept. 27–29. The American Institute of Chemical Engineers is sponsoring an Atomic Exposition in conjunction with a nuclear congress in Cleveland, Dec. 12–17.

R. T. Sawyer, American Locomotive Company's manager of research, is chairman of the Forum's exhibit committee. Manufacturers and potential operators of reactors, components and associated apparatus, producers of instruments and equipment for isotope users, and other companies providing products or services to the atomic energy industry can obtain exhibit space.

AIChE has named A. F. Denham (Atomic Exposition, 931 Book Bldg., Detroit 26, Mich.) to direct its exhibit. Cleveland Municipal Auditorium will be the site of both the exposition and the nuclear congress meetings.

The nuclear congress, being arranged by Engineers Joint Council, is being sponsored by 14 societies.

Nautilus Sails on Tests, Navy Expands Training

On January 17, the *Nautilus* cast off from her dock and, at 11:01 am, signaled that she was "under way on nuclear power." This first use of nuclear power for propulsion had been delayed three months by installation of incorrect steam piping.

The second nuclear-powered submarine, the *Sea Wolf*, will be launched this year. Navy is stepping up its officer training program in nuclear engineering and other phases of nuclear power. Naval officers have been invited to apply for two postgraduate courses starting this summer. Deadline for applications is Feb. 18.

The 15-month advanced nuclear engineering course at Massachusetts Institute of Technology will be expanded from 6 to 16 officers, and the 3-year mechanical engineering (nuclear power) course at the Naval

Industrial Applications

Potato-irradiation treatment competitive. For far less than the cost of shipping from the Far West or South, Northern potato processors can irradiate the local product and store it to keep their plants at full capacity the year around. With three fourths of total potato production harvested in the fall, storage until needed is a real problem, for even with refrigeration it is difficult to hold untreated potatoes later than May. But studies at Brookhaven (NU, Aug. '54, p. 16) have shown that doses of 10,000–20,000 rep stop sprouting for 18 months without affecting taste. Comprehensive studies of two plant designs at the U. of Michigan indicate total irradiation costs (including plant operation and 10-yr amortization) of $3.62–4.98 per ton.

One plant would irradiate 270 bushels per hour to 10,000 rep by passing sacked or bulk potatoes on a tray conveyor through a 3-ft concrete walled chamber containing 150,000 curie source. Source is either Ce^{137} (ORNL is building fission-product separation plant with 200,000 curie/yr Ce^{137} capacity), or 2-yr-old mixed fission products. Slightly different design uses source composed of two reactor fuel elements that are in the cooling-off period between reactor irradiation and chemical processing. Fuel-element plant would provide lowest total irradiation cost if elements were rented for $250 per month apiece.

Economic comparisons are complicated as different source half-lives mean differing renewal costs. Building is estimated at $66,000 ($49,000 if cooling slugs are source), sources at $120,000 for Ce and $38,000 for MFP. Cesium source cost is scaled-up from present price of $6,000 for 1,000 curie using 0.6 power scale-up factor commonly applied to chemical-plant costs.

Tracer studies yield better water distribution. Good water distribution is usually important in irrigating sugar cane fields, as aqueous ammonia fertilizer is added to irrigation water. Radiorubidium has been used by Hawaiian Sugar Planters' Association to study distribution on all of Hawaii's irrigated sugar plantations. From these tests modifications of line length and slope are formulated to insure even distribution. Procedure is simultaneous delivery of controlled water supply and tracer rubidium to irrigation line, followed by spot checks at various locations with Geiger counter to estimate amount of water absorbed, and taking soil and water samples for activity analysis.

Isotopes show leak location. A new system saves 25% in time and cost and also is better suited for more exacting specifications works by facilitating communications in the two-man job of pressure testing fuselage and other aircraft components. In former method part under test was pressurized and outside man located leaks by hissing sound of escaping air. Using head set, he directed a man inside the part to the leak, and inside man applied sealants. Complicated structural shapes and shop and air noise often made verbal instruction difficult.

All this has been changed at Rohr Aircraft Corp., Chula Vista, Calif. Outside man now spots a glass-encapsulated low-activity source on the leak. Aided by Geiger counter, inside man pinpoints leak, then applies sealant.

Tritium determines moisture gradient in attached protective films. See p. 76 for two-page article on this new test method.

ROUNDUP

Postgraduate School, Monterey, Calif., will start with 28 men.

The MIT course is concerned with design, development and construction of nuclear powered vessels, while the NPS program is aimed at more practical training for operational maintenance of nuclear powered installations. But some NPS student officers spend their third year at Oak Ridge School of Reactor Technology, with work paralleling the MIT program.

AEC Awards $1.2-Million for Physical Research

Universities and private research institutions were awarded 49 unclassified physical research contracts by the Atomic Energy Commission last month. Included in the total of $1,214,590 is $79,854 for six new contracts.

RAW MATERIALS

SOUTH AFRICA: will build ore plant to meet British demand. The British Atomic Energy Authority has agreed to buy uranium from the Rhokana Corp. of Northern Rhodesia. The company will mine the uranium and treat it in a plant to be erected. But deposit is small, and the profit will be only a small part of the company's total.

WEST GERMANY: investigating uranium resources. Sixteen industrial trusts, with the government a silent partner, have banded together in the German Association for Physical Research. The unit, capitalized at $740,000, will survey known deposits near the East German border and in the Bavarian forest to see if they can meet future requirements of 10,000 tons of natural uranium a year. Grants for physical research also will be made.

UNITED STATES: increase processing plant capacity; new corporation formed. AEC has amended a contract with Vanadium Corp. of America to increase capacity of its Naturita uranium processing plant in Colorado. It's the seventh expansion of Colorado Plateau facilities in less than eight months.

Vitro Corp. of America and Rochester & Pittsburgh Coal Co. have formed a jointly-owned subsidiary, Vitro Minerals Corp. The new corporation will explore, drill and mine uranium claims held by the two companies in Wyoming, Utah, and Canada. Jack O. Horton of Vitro Uranium Co. will be general manager of Vitro Minerals.

News in Brief

Nuclear power gets Franklin Institute attention. A major activity of the new heat and power research section of the Franklin Institute, Philadelphia, will be study of power-reactor problems. F. L. Jackson heads the new section.

Compiling eight-year isotope summary. AEC's Isotopes Division has queried all users of radioisotopes to gather data for a follow-up to the five-year summary of U. S. isotope distribution. Since the last publication, number of institutions receiving shipments has tripled.

VA needs radioisotope specialists. Civil-service jobs for biologists, biochemists and physicists are open in radioisotope units at Veterans Administration centers throughout the country. Pay is as high as $9,600 a year; more data is supplied by U. S. Civil Service Commission, Washington 25.

Harwell school fully booked to April. The isotope school at Britain's Atomic Energy Research Establishment, Harwell, is now accepting applications for its 27th and 28th courses. But these 4-week training periods don't start until April 25 and June 27. Latest alumni count for this techniques course was 329 from 29 countries.

ORSORT adds tuition fee. Oak Ridge School of Reactor Technology will charge students sponsored by private industry or other agencies a tuition fee of about $2,500 starting with the '55-56 term. Policy of no tuition continues for student employees of ORNL, government employees, and employees of AEC cost-type contractors. Application deadline for course starting in fall is March 14.

Making thulium units available for loan. Thulium sources and X-ray units (NU, May '54, p. 35)—20 of each—will shortly be available from Argonne National Laboratory for development and testing. Qualified industrial firms and nonprofit groups can rent them for three-month periods.

Australian school will build two reactors. The University of Sidney is planning two low-power reactors for training (in conjunction with postgraduate nuclear courses), isotope production and research. These will complement Australia's 10,000-kw power reactor now being planned.

NBS establishes advisory committees. Over the past year, the National Bureau of Standards has set up 12 groups representing professional societies interested in its work. Radiation physics is being covered by a committee headed by F. Seitz of the U. of Illinois for the American Institute of Physics, with L. D. Marinelli as radiological consultant.

Israel, France cooperate on heavy-water research. The Weizmann Institute of Science's department of isotope research in Israel has evolved a chemical process not requiring electricity for heavy-water manufacture. Pilot plant tests are under way, with parallel tests going on in France. The two countries are also exchanging scientists on the program.

First Navy Jack, which unfurled the historic warning to the world in 1775—believed to have been first hoisted to the jackstaff of the ALFRED by one Lieut. John Paul Jones.

naval history is being made today

At 0955 on January 5th, one of the major events in naval aviation history took place.

It was the unveiling of the United States Navy's great new XP6M SeaMaster—Ship No. 1 and prototype of an entirely new concept in military aircraft.

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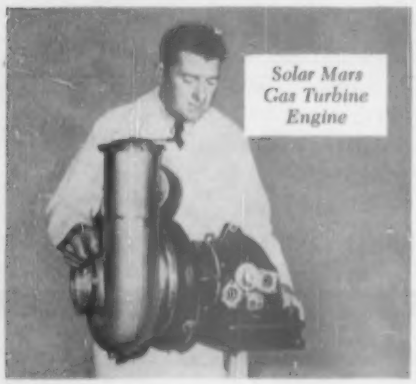

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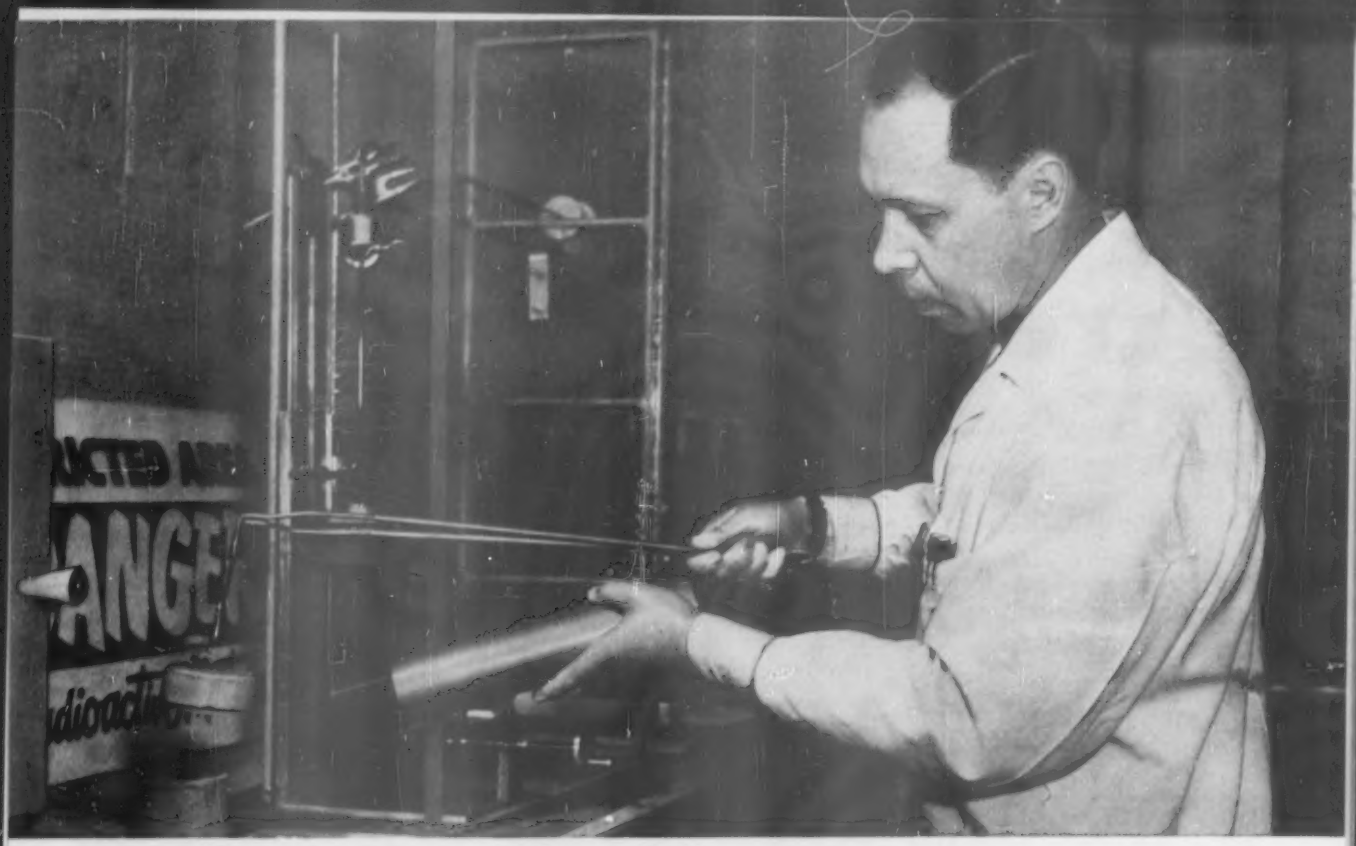

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GENERAL ELECTRIC

NUCLEONICS FEBRUARY, 1955

Jerome D. Luntz, *Editor*

Balance Sheet

OFF TO A SLOW START, the power reactor development program in this country is now in full swing. Five plants in various stages of design and construction will, when completed, do much to point the direction towards economic nuclear power.

Although industry is making a major contribution in the role of contractor on several of the above government plants and has also begun to spend its own money, no industry-owned plants are yet being engineered. The reasons for this are quite clear. Industry has been operating for only five months under a law that makes it possible for the first time to own reactors. Straight dollars-and-cents risk on investment in nuclear plants is high. But perhaps of overriding importance is the unavailability of adequate insurance coverage for reactors.

Despite all this, several companies have been giving serious and detailed consideration to footing the bill 100% on the building of nuclear power plants. It seems probable that at least one will take the plunge in '55.

It is in this atmosphere that the Atomic Energy Commission has announced its "power demonstration reactor program" (see p. 7) wherein AEC would select certain industry proposals for financial support. The program has met mixed reaction in the industry. It is expected that some proposals will be submitted but that there will not be a rash of them.

WHY HAS THE PLAN gotten mixed reaction? Is it good for the industry? Below is our analysis of it.

Credits:

1. Promulgation of the plan shows a positive desire on the part of AEC to foster the development of a nuclear power industry. Broadening the base of activity beyond the AEC installations is sure to hasten the day of civilian nuclear power.

2. The plan could expedite what is perhaps the most important need—getting plants built and in operation so that experience and knowhow can be gained.

Debits:

1. There may be a tendency on part of some companies to delay serious consideration of "going it alone" without government help. This could hurt both progress and the taxpayer.

2. Early date for receipt of proposals (April 1) may prevent some groups from getting in on the show and others from being able to come through with "quality" proposals.

3. Price schedule for AEC purchase of fissionable material and types of proposals accepted may influence course of technical developments, e.g., whether or not a plant is optimized for plutonium or power production, discouragement of advanced designs, etc.

4. "Assurance of completion" criterion may also deter advanced thinking.

RECOMMENDATIONS:

To AEC—

1. Give greatest preference to those proposals that will advance the art most.

2. At the same time, try to avoid forcing the technology in any particular direction. Do not favor certain types of designs. Let the industry take the basic responsibility for setting its paths.

3. Be flexible on date. Perhaps accept only one proposal on April 1 and as many others as budget permits six months later. But let it be known in advance that this policy exists.

4. Do not take small response from industry as meaning industry is abdicating its interest in the field. Rather recognize the problems industry is facing and keep the offer an open one. Also, make it clear to industry that applications for 104b licenses need not fall under this program and that uranium availability need not be a limitation on number of licenses issued.

To industry—

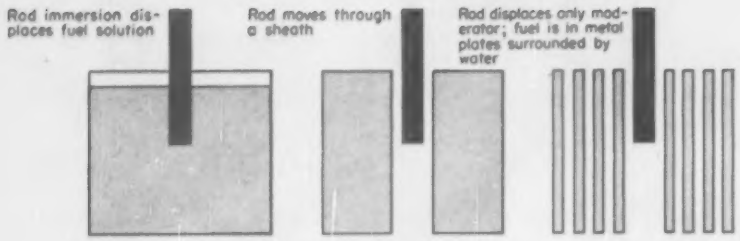
1. In proposals to be submitted, place greatest emphasis on advancement of art rather than on minimizing amount of financial support to be requested.

2. Make your proposals contingent upon resolution of plant insurance problem so as to hasten Federal examination of such needs.

3. Because AEC has not yet set fuel recovery charges, industry should weigh desirability of submitting chemical processing plant plan as part of power reactor proposal.

4. Don't lose sight of benefits of 100% private investment in plants.

Once again it is clear that an industry-government partnership will be necessary in the atomic energy field for at least the next several years. Progressive thinking on the part of both partners is vital.


Rod immersion displaces fuel solution
Rod moves through a sheath
Rod displaces only moderator; fuel is in metal plates surrounded by water

Reactor Control-Rod Theories

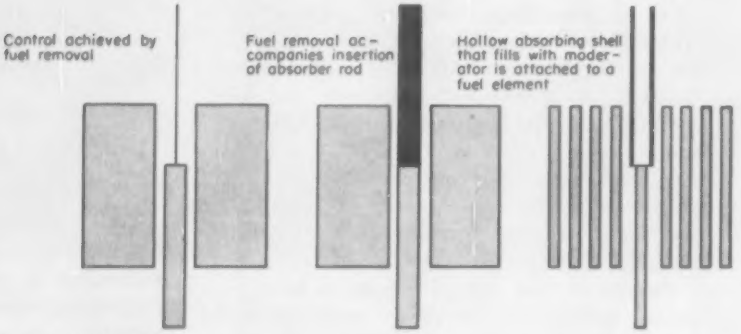

Control achieved by fuel removal
Fuel removal accompanies insertion of absorber rod
Hollow absorbing shell that fills with moderator is attached to a fuel element

FIG. 1. Control-rod:core arrangements

An examination of the physical assumptions on which two popular control-rod theories are based suggests a more logical theory that better predicts the reactivity effects

By RAYMOND L. MURRAY and JOHN W. NIESTLIE
Department of Physics, North Carolina State College, Raleigh, N. C.

IN THE DESIGN of small nuclear reactors that operate at high neutron-flux levels, the transient concentration of certain fission-product poisons makes it necessary to provide large reactivity control by neutron-absorbing rods (*1*). Further, if the reactor is initially heavily loaded with fuel to accommodate subsequent burnup, the resulting excess reactivity must be balanced by strongly absorbing elements. Such control rods may constitute an appreciable volume of the reactor and play a more important role in determining the neutron balance than in large natural-uranium heterogeneous reactors of the Oak Ridge or Brookhaven type.

Figure 1 shows a few of the possible physical arrangements of control rods in a reactor core. The reactivity value of each of these arrangements is determined from the critical conditions in the fully inserted and fully withdrawn configurations. Since differences between theories hinge on the assumptions made regarding the nature of the fast flux in the vicinity of a rod, principal attention will be directed toward the simplest case—a cylindrical absorbing element located on the central axis of a cylindrical assembly of fissionable material as shown in Fig. 2.

Theories

Two-group diffusion theory (*2*) forms the basis for deriving critical dimensions of a reactor with a control rod. The conventional group equations for the reactor core are

$$D_1\nabla^2\phi_1 - \Sigma_1\phi_1 + k\Sigma_2\phi_2 = 0 \quad (1)$$
$$D_2\nabla^2\phi_2 - \Sigma_2\phi_2 + \Sigma_1\phi_1 = 0 \quad (2)$$

In cylindrical coordinates, the most general solutions for the fast flux ϕ_1 and the thermal flux ϕ_2 in a cylinder of finite height H are

$$\phi_1 = X + Y \quad (3)$$
$$\phi_2 = S_1X + S_2Y \quad (4)$$

where, in terms of the ordinary and modified Bessel functions

$$X = AJ_0(\mu r) + BY_0(\mu r) \quad (5)$$
$$Y = CI_0(\nu r) + EK_0(\nu r) \quad (6)$$

Here $\mu^2 + (\pi/H)^2$ and $-\nu^2 + (\pi/H)^2$ are the roots of the buckling B^2 in

the compatibility condition $(1 + B^2L^2)(1 + B^2\tau) = k$, and S_1 and S_2 are the coupling coefficients. The flux coefficients A, B, C and E and the critical dimensions (or core composition) are next determined by the application of boundary conditions on the fluxes. For a cylindrical multiplying medium without reflector, the requirement that ϕ_1 and ϕ_2 vanish at the extrapolated external boundary R yields relations between two sets of coefficients: $B/A = -J_0(\mu R)/Y_0(\mu R)$ and $E/C = -I_0(\nu R)/K_0(\nu R)$.

At this point in the analysis the differences between methods appear. The assumption regarding the boundary condition to be applied to the fast flux ϕ_1 in the vicinity of the control rod is the distinguishing feature.

1. Fast Flux Finite at $r = 0$

In Method 1, the one most widely used (3), it is assumed that the fast flux must remain finite everywhere, despite the singularities in the functions Y_0 and K_0. Noting that the limit of the ratio $Y_0(\mu r)/K_0(\nu r)$ as r approaches zero is $-2/\pi$, one makes a choice of the ratio $B/E = \pi/2$. The contribution of the singular terms vanishes at the origin, while terms involving J_0 and I_0 remain finite.

Finally, assuming the rod to be black to thermal neutrons, one sets the core flux equal to zero at the extrapolated radius b, which is smaller by a distance of the order of $0.71\lambda_t$ than the actual rod radius a. The critical condition derived from the equations for the arbitrary coefficients is

$$\begin{vmatrix} J_0(\mu b) & \frac{S_2}{S_1} I_0(\nu b) & \\ J_0(\mu R) & 0 & \\ 0 & I_0(\nu R) & \\ & Y_0(\mu b) + \frac{2}{\pi}\frac{S_2}{S_1} K_0(\nu b) & \\ & Y_0(\mu R) & \\ & \frac{2}{\pi} K_0(\nu R) & \end{vmatrix} = 0 \qquad (7)$$

The third row may be divided by $I_0(\nu R)$. Since the ratio K_0/I_0 is very small in comparison with the other terms in the third column for $\nu R \gg 1$, and the cofactors of K_0 and I_0 are of the same order of magnitude, Eq. 7 can be approximated accurately by the working formula

$$\frac{J_0(\mu R)}{Y_0(\mu R)} = \frac{J_0(\mu b)}{Y_0(\mu b) + \frac{2}{\pi}\frac{S_1}{S_2} K_0(\nu b)} \qquad (8)$$

The flux distributions can be formed from Eqs. 3–6 using arbitrary coefficients

$$\begin{matrix} A = -M/\psi & C = -\chi \\ B = M & E = 1 \end{matrix} \qquad (9)$$

where $\psi = J_0(\mu R)/Y_0(\mu R)$ and $\chi = K_0(\nu R)/I_0(\nu R)$. For Method 1

$$M = \pi/2 \qquad (10)$$

Figure 3 shows an example of fluxes calculated by Method 1 using Eqs. 9 and 10 for a bare cylindrical reactor containing U^{235}, metal, and water. The composition is such that $\mu = 0.09188$, $\nu = 1.1140$, $S_1 = 0.11634$ and $S_2 = -13.780$. The critical radius with a control rod of radius 4.39 cm is found from Eq. 8 to be 33.68 cm.

Two features of Fig. 3 are notable: (a) the fast flux goes strongly negative until a very short distance from the origin, after which it rises sharply to its required finite value; (b) the slope of the fast flux at the rod surface is positive, which suggests a strong fast-neutron current into the rod. It is apparent that such a current has no physical meaning, since the rod was not assumed to have any absorption for fast neutrons. For this example, the slope of the fast flux is such that it extrapolates to zero at a distance 4.0 cm within the rod, although the curve goes to zero at 2.7 cm from the boundary.

2. Flat Fast Flux at $r = a$

Method 2 is based on no absorption or moderation of fast neutrons in control-rod materials. It is assumed (4) that the slope of the fast flux ϕ_1' is zero at the rod surface, at radius a. The condition on thermal flux at a is that $\phi_2/\phi_2' = d_2$, the thermal extrapolation distance. To simplify the analysis, the following approximations are made: $J_0(\mu a) \simeq 1$, $J_1(\mu a) \simeq 0$, $I_0(\nu a) \simeq 1$ and $I_1(\nu a) \simeq 0$. If the rod is very small, these evidently are admissible. A critical condition is derived from Eqs. 1–6. The working formula of Method 2 is

$$\frac{J_0(\mu R)}{Y_0(\mu R)} = \left[Y_0(\mu a) + d_2 Y_1(\mu a) - \frac{S_2 \mu Y_1(\mu a)}{S_1 \nu K_1(\nu a)} \left\{ K_0(\nu a) + \nu d_2 K_1(\nu a) - \frac{K_0(\nu R)}{I_0(\nu R)} \right\} \right]^{-1} \qquad (11)$$

For many reactors, the ratio $K_0(\nu R)/I_0(\nu R)$ is completely negligible, and the functions dependent on rod and reactor radii are separated.* The coefficients of the flux distributions of Method 2 also are given by Eq. 9, except that

$$M = -\frac{\nu K_1(\nu a)}{\mu Y_1(\mu a)} \qquad (12)$$

where, again, approximations related to rod size are made. Formally, the fluxes become infinite at the origin.

The critical condition Eq. 11 was applied to the example reactor, assuming the same fuel loading and composition as before. The critical core radius was found to be 26.52 cm, much smaller than by Method 1. In fact, it is almost equal to the radius of core without any control rod, $2.405/\mu = 26.17$ cm.

Figure 4 shows the fast and thermal fluxes for this system, based on Eq. 12. The fast flux does not have zero slope at the rod surface, as was specified in the derivation. The negative slope suggests a strong fast-neutron *source* within the rod. This discrepancy readily can be shown to be due to the approximations of small rod size that actually are not met for a 4.39-cm-radius control rod. Examination of the results calculated by Methods 1 and 2 shows good correlation between the calculated slope of the fast flux and the efficacy of the control rod. From a physical standpoint, there is a clear implication that the *true* degree of attenuation of the fast group in the rod is

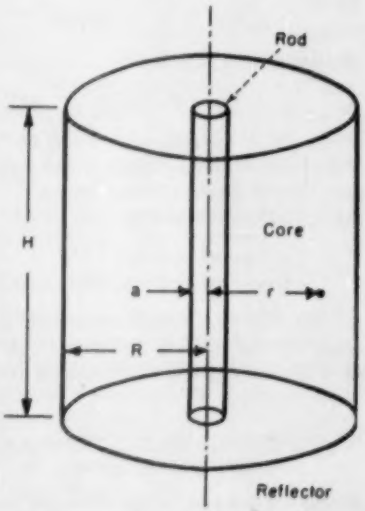


FIG. 2. Cylindrical reactor with central control rod

* It should be noted that $\mu Y_1(\mu a)/\nu K_1(\nu a)$ may not be close to $-2/\pi$ as suggested in ref. (4).

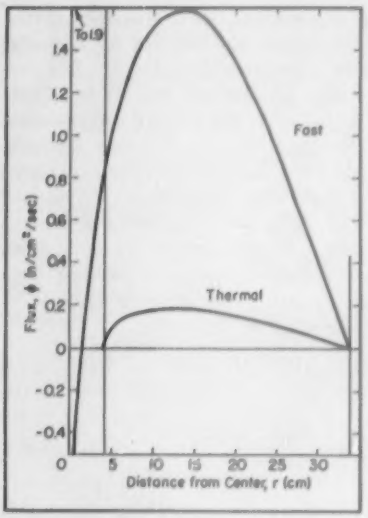


FIG. 3. Flux distributions by Method 1. Fast flux rises to 1.9 at $r = 0$

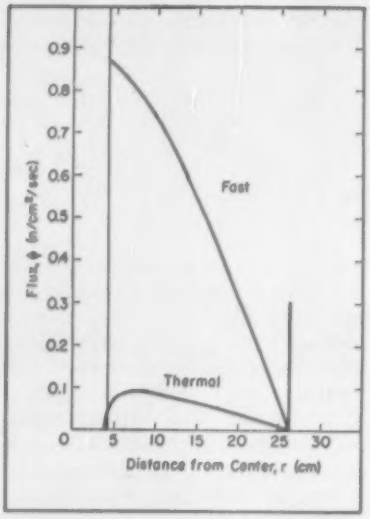


FIG. 4. Flux distributions by Method 2

important in determining the effect of a control rod on reactivity.

3. General Method

Development of a general method involves assuming correct fast-flux boundary conditions. A suitable description of the fast flux at the rod surface requires that cognizance be taken of possible designs. Several arrangements are practicable: (a) a solid rod composed of cadmium or its alloy with another metal, a boron compound, or a boron-impregnated metal; (b) a hollow tube or one filled with an element of low moderating ability; (c) an absorbing cylindrical shell that contains moderating material.

The fast flux will be essentially flat if the rod is hollow or if the rod consists of metal of high atomic weight, since the moderation and attenuation of fast neutrons will be small. However, if the rod is composed of boron carbide or is filled with water, there will be an appreciable amount of energy loss in the rod region, which would correspond to a certain amount of fast leakage into it. No fast neutrons are formed in the rod, assuming it is devoid of fissionable material. The magnitude of such effects can be described by treating the control rod as a separate medium that has the effect of an internal reflector for fast neutrons. If the rod is a solid strong absorber, it can sustain no thermal flux; however, energy loss of fast neutrons can cause a build-up of thermal neutrons in a moderator-filled absorbing shell.

The appropriate differential equation for the fast group in such a control cylinder is

$$D_{1r}\nabla^2\phi_{1r}(r,z) - \Sigma_{1r}\phi_{1r}(r,z) = 0$$

The ratio D_{1r}/Σ_{1r} is identified with the age τ_r of the medium. If the axial flux in a finite cylinder of height H is given by the function $\cos(\pi z/H)$, the radially dependent flux can be shown to be given by

$$\nabla^2\phi_{1r}(r) - \varkappa_{1r}^2\phi_{1r}(r) = 0$$

where

$$\varkappa_{1r}^2 = (1/\tau_r) + (\pi/H)^2$$

The regular solution is

$$\phi_{1r}(r) = F_r I_0(\varkappa_{1r}r) \qquad (13)$$

where F_r is an arbitrary coefficient. The equations of continuity of fast flux and current across the boundary separating rod r and core c are

$$\begin{aligned}\phi_{1r}(a) &= \phi_{1c}(a)\\ D_{1r}\phi_{1r}'(a) &= D_{1c}\phi_{1c}'(a)\end{aligned} \qquad (14)$$

An effective *fast* extrapolation length equal to the ratio of the flux to its slope at the rod boundary can be derived from Eqs. 13 and 14:

$$d_1 = \frac{\phi_{1c}(a)}{\phi_{1c}'(a)} = \frac{D_{1c}}{D_{1r}}\frac{I_0(\varkappa_{1r}a)}{\varkappa_{1r}I_1(\varkappa_{1r}a)} \qquad (15)$$

If the control rod of the example reactor used in the previous calculations were filled with water of age $\tau_r =$ 31.4 cm², then d_1 would be 11.4 cm, lying between the assumed infinity for Method 2 and the apparent 4 cm according to Method 1.

The extrapolation distance for the thermal group is readily obtained from Fig. 5's graph of d_2/λ_t as a function of a/λ_t, where λ_t is the core transport mean free path (*5*).

Formulas for the critical condition and flux distribution are derived in the following sections for the general case of finite extrapolation distances for both fast and thermal fluxes, with only such approximations as can be completely justified. Convenient calculation relations are provided.

Bare Reactor

The fluxes that satisfy the coupled two-group Eqs. 1 and 2 are taken again to be of the form given by Eqs. 3–6: $\phi_1 = X + Y$, $\phi_2 = S_1X + S_2Y$, where $X = AJ_0(\mu r) + BY_0(\mu r)$ and $Y = CI_0(\nu r) + EK_0(\nu r)$. The condition that the fluxes go to zero at the extrapolated boundary of the core requires that

$$X(R) = 0 \qquad (16)$$
$$Y(R) = 0 \qquad (17)$$

The fluxes are assumed to extrapolate to zero within the rod at distances d_1 and d_2, such that $\phi_1(a)/\phi_1'(a) = d_1$ and $\phi_2(a)/\phi_2'(a) = d_2$, or

$$X/d_1 - X' + Y/d_1 - Y' = 0 \qquad (18)$$
$$S_1(X/d_2 - X') + S_2(Y/d_2 - Y') = 0 \qquad (19)$$

where the evaluation is at the actual rod radius a. The distance d_1 is determined by use of Eq. 15. The critical determinant

$$\Delta = \begin{vmatrix} J_0(\mu R) & Y_0(\mu R) & 0 & 0\\ 0 & 0 & I_0(\nu R) & K_0(\nu R)\\ a_{31} & a_{32} & a_{33} & a_{34}\\ a_{41} & a_{42} & a_{43} & a_{44}\end{vmatrix} \qquad (20)$$

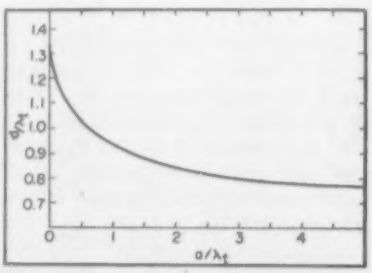


FIG. 5. Thermal extrapolation length for black control cylinder

can be formed from the coefficients of A, B, C and E in the four simultaneous Eqs. 16, 17, 18, 19. In Equation 20

$$a_{31} = \frac{J_0(\mu a)}{d_1} + \mu J_1(\mu a)$$

$$a_{32} = \frac{Y_0(\mu a)}{d_1} + \mu Y_1(\mu a)$$

$$a_{33} = \frac{I_0(\nu a)}{d_1} - \nu I_1(\nu a)$$

$$a_{34} = \frac{K_0(\nu a)}{d_1} + \nu K_1(\nu a)$$

$$a_{41} = S_1 \left\{ \frac{J_0(\mu a)}{d_2} + \mu J_1(\mu a) \right\}$$

$$a_{42} = S_1 \left\{ \frac{Y_0(\mu a)}{d_2} + \mu Y_1(\mu a) \right\}$$

$$a_{43} = S_2 \left\{ \frac{I_0(\nu a)}{d_2} - \nu I_1(\nu a) \right\}$$

$$a_{44} = S_2 \left\{ \frac{K_0(\nu a)}{d_2} + \nu K_1(\nu a) \right\} \qquad (21)$$

Setting $\Delta = 0$, and noting that a_{33}, a_{43} and $K_0(\nu R)$ are much less than $I_0(\nu R)$ for most reactors, the critical relation for a bare reactor by Method 3 may be simplified to

$$\psi = \frac{J_0(\mu R)}{Y_0(\mu R)} = \frac{a_{31}a_{44} - a_{41}a_{34}}{a_{32}a_{44} - a_{42}a_{34}} \qquad (22)$$

The right side, dependent on rod radius a, is a slowly varying function of fuel loading; the left side is a rapidly varying function, but one that is quickly computed. Graphical methods of solving for the unknown quantities are recommended.

The flux distributions for the core of the bare reactor by Method 3 can be formed from Eq. 9, but with

$$M = \frac{a_{34}}{a_{31}/\psi - a_{32}} \qquad (23)$$

The thermal flux within the rod can be evaluated by considering the rod as a central reflector. The radial fast flux is given by Eq. 13. The radially dependent thermal flux is the solution of the inhomogeneous equation

$$\nabla^2\phi_{2r} - \kappa_{2r}^2\phi_{2r} + \phi_{1r}\frac{\Sigma_{1r}}{D_{2r}} = 0$$

where $\kappa_{2r}^2 = 1/L_{2r}^2 + (\pi/H)^2$. By standard methods (2), the solution is

$$\phi_{2r} = G_r I_0(\kappa_{2r}r) + S_2 F_r I_0(\kappa_{1r}r) \qquad (24)$$

where F_r is fixed by the condition $\phi_{1r}(a) = \phi_{1c}(a)$. Applying the extrapolation condition $\phi_{2r}(a)/\phi_{2r}'(a) = -d_2$, it is found that

$$G_r/F_r = -S_2[d_2\kappa_{1r}I_1(\kappa_{1r}a) + I_0(\kappa_{1r}a)]/$$
$$[d_2\kappa_{2r}I_1(\kappa_{2r}a) + I_0(\kappa_{2r}a)] \qquad (25)$$

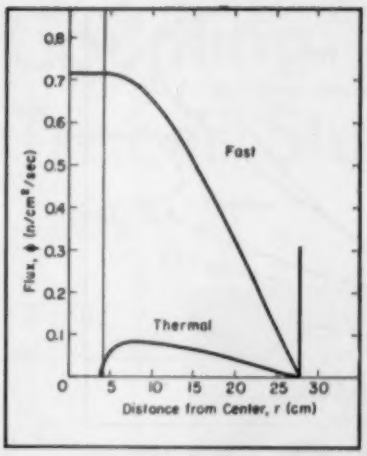


FIG. 6. Flux distributions by the general Method 3, for hollow shell of material black to thermal neutrons

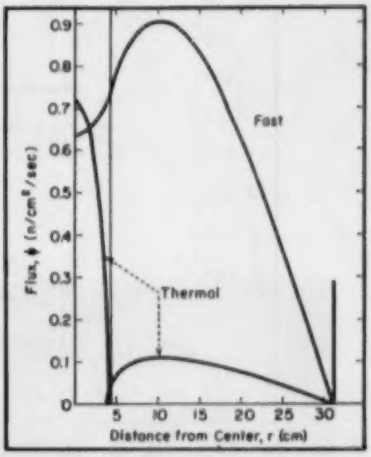


FIG. 7. Flux distributions by the general Method 3, for water-filled shell of material black to thermal neutrons

The critical Eq. 22 was applied to the example reactor, for two cases. For a hollow shell, with fast-flux slope zero at the rod surface ($d_1 = \infty$), the critical core radius was found to be 27.80 cm. For a shell filled with water of age 31.4 cm² ($d_1 = 11.4$ cm), the critical radius was 31.10 cm. The effect of the sink of fast neutrons in the rod is to increase the reactivity value of the rod. Figures 6 and 7 show the flux distributions for these two systems using Eqs. 23 and 3–6.

The slope of the fast flux is zero in the case of the hollow tube, Fig. 6, in accord with assumption. The continuation of the fast-flux curve within the water core of the rod in Fig. 7 is based on Eq. 12, while the thermal flux is given by Eqs. 24 and 25. The high value of the flux inside the absorbing shell is due to the thermalization of the fast neutrons that flow into the rod from the core proper.

Reflected Reactor

The extension of the general method to the infinitely reflected reactor involves: (a) solution of the two-group reflector equations; and (b) application of a condition of continuity of fluxes and currents at the core radius R. Four new equations supplement Eqs. 16 and 17.

$$X + Y = FZ_1$$
$$S_1X + S_2Y = GZ_2 + S_3FZ_1$$
$$X' + Y' = \frac{D_{1r}}{D_{1c}}FZ' \qquad (26)$$
$$S_1X' + S_2Y' = \frac{D_{2r}}{D_{2c}}(GZ_2' + S_3FZ_1')$$

where the notation is conventional (2). Abbreviations are defined: $X_1 = J_0(\mu r)$, $X_2 = Y_0(\mu r)$, $Y_1 = I_0(\nu r)$, $Y_2 = K_0(\nu r)$. The critical determinantal equation becomes

$$\begin{vmatrix} X_1 & X_2 & Y_1 & Y_2 & & & & \\ S_1X_1 & S_1X_2 & S_2Y_1 & S_2Y_2 & & & & \\ X_1' & X_2' & Y_1' & Y_2' & & & & \\ S_1X_1' & S_1X_2' & S_2Y_1' & S_2Y_2' & & & & \\ a_{31} & a_{32} & a_{33} & a_{34} & & & & \\ a_{41} & a_{42} & a_{43} & a_{44} & & & & \\ & & -Z_1 & 0 & & & & \\ & & -S_2Z_1 & -Z_2 & & & & \\ & & -\frac{D_{1r}}{D_{1c}}Z_1' & 0 & & & & \\ & & -\frac{D_{2r}}{D_{2c}}S_2Z_1' & -\frac{D_{2r}}{D_{2c}}Z_2' & & & & \\ & & 0 & 0 & & & & \\ & & 0 & 0 & & & & \end{vmatrix} = 0 \qquad (27)$$

where the a's are the same as those defined for the bare reactor. The equation can be simplified by the following steps: (a) dividing columns 1, 2, 5 and 6 of the determinant in order by X_1, X_2, $-Z_1$, and $-Z_2$; (b) setting the first four terms in column 4 equal to zero, in view of the small size of $K_0(\nu R)$ and $K_1(\nu R)$; (c) setting the last two terms of column 3 equal to zero because of the large values of $I_0(\nu R)$ and $I_1(\nu R)$; (d) dividing columns 3 and 4 by $I_0(\nu R)$ and $K_0(\nu R)$ respectively. After rearrangement, the critical condition

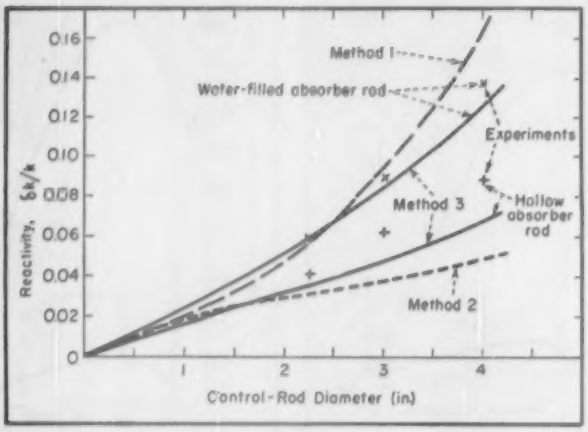


FIG. 8. Experimental and calculated reactivity values of central control rods

by Method 3 is

$$\alpha = \alpha' + [\psi(a)/\psi(R)](\epsilon - \alpha') \quad (28)$$

where

$$\alpha' = \frac{\rho_e \delta C_1 + \rho_f \gamma C_2 + \beta C_3}{C_1 + C_2 + C_3}$$

$$C_1 = S_1(\rho_f \gamma - \beta)$$

$$C_2 = S_2(\beta - \rho_e \delta)$$

$$C_3 = S_3 \rho_e (\delta - \gamma)$$

$$\rho_f = \frac{D_{1r}}{D_{1c}}$$

$$\rho_e = \frac{D_{2r}}{D_{2c}}$$

$$\psi(a) = \frac{a_{21}a_{44} - a_{41}a_{24}}{a_{22}a_{44} - a_{42}a_{24}}$$

$$\psi(R) = \frac{J_0(\mu R)}{Y_0(\mu R)}$$

and

$$\alpha = \frac{X_1'}{X_1}\Big]_R = -\mu \frac{J_1(\mu R)}{J_0(\mu R)};$$

$$\epsilon = \frac{X_2'}{X_2}\Big]_R = -\mu \frac{Y_1(\mu R)}{Y_0(\mu R)}$$

$$\beta = \frac{Y_1'}{Y_1}\Big]_R = \nu \frac{I_1(\nu R)}{I_0(\nu R)} \simeq \nu - \frac{1}{2R} - \frac{1}{8\nu R^2}$$

$$\gamma = \frac{Z_1}{Z_1}\Big]_R = \frac{-\kappa_{1r} K_1(\kappa_{1r} R)}{K_0(\kappa_{1r} R)} \simeq -\kappa_{1r} - \frac{1}{2R} + \frac{1}{8\kappa_{1r} R^2}$$

$$\delta = \frac{Z_2'}{Z_2}\Big]_R = \frac{-\kappa_{2r} K_1(\kappa_{2r} R)}{K_0(\kappa_{2r} R)} \simeq -\kappa_{2r} - \frac{1}{2R} + \frac{1}{8\kappa_{2r} R^2}$$

The approximate expressions for β, γ and δ are very accurate for the radii and compositions of many reactors. The right side of Eq. 29 is quite insensitive to variations of fuel concentration of the core, which expedites iteration. Thus, accurate solutions often are possible with only one trial choice of size or loading.

It should be noted that the formula for the reflected reactor with control rod reduces to one conveniently applicable to a reactor with no rod. Upon setting $\psi(a) = 0$, Eq. 28 reduces to

$$\alpha = \alpha' \quad (29)$$

for no control rod. This relation serves as a substitute for solving the usual determinantal equation for a reflected core (*2*). In practice, it may be sufficient to evaluate the side reflector savings for a reactor without a central rod and to perform all calculations for a bare equivalent cylinder.

To illustrate, Eqs. 28 and 29 were used in calculating the example reactor. *Without* a water-filled control rod, the calculation yields a 26.17 cm radius for the bare cylinder and 21.58 cm for the side-reflected cylinder—a saving of 4.59 cm. *With* the rod, the bare cylinder is calculated as 31.10 cm, the side-reflected cylinder's radius is 26.49 cm—a saving of 4.61 cm.

Comparison With Experiment

To test the general method for evaluating control-rod worth, calculations were made for a configuration for which experiments have been reported by R. O. Brittan et al of Argonne National Laboratory. These critical experiments were performed on water-reflected water-moderated MTR-type assemblies. Without a control rod, the critical height of the 26.3-cm-radius cylindrical core was determined to be 35.4 cm. Measurements of height were obtained for rods having an absorbing shell with either a removable aluminum metal core or a water core.

The computation procedure consisted of: (a) evaluation of group constants for the assembly and calculation of the end and radial reflector savings (latter were obtained by solving the problem of the side-reflected cylinder); (b) application of the several theories to the equivalent bare reactor, using the same fuel concentration and end reflector savings as found in the first step; (c) calculation of the reactivity value of the control rod from the critical multiplication factors with and without a rod.

Figure 8 shows the experimental data and calculated curves of reactivity versus rod diameter by Methods 1 and 2, and by Method 3 for a water core and with no core. Several trends can be noted. Method 1 appears to overestimate the reactivity effect for large rods, while Method 2 underestimates the effect. Method 3 is able to distinguish the reactivity values of rods with water cores and with metal cores and to reproduce experimental results with reasonable accuracy. Comparison of experimental results with the limiting no-moderation solution indicates that there is a perceptible amount of moderation in the aluminum in the rod's core.

Since actual reactivity effects of control rods in a reactor are strongly dependent on rod radius, it is concluded that use of the less rigorous methods may lead to serious over- or underestimates of the degree of reactor control. Similar conclusions can be drawn regarding the effects of multiple off-center control rods. The general method provides greater accuracy.

* * *

Suggestions made by members of the staff of Oak Ridge National Laboratory are recognized gratefully.

BIBLIOGRAPHY

1. R. L. Murray, "Introduction to Nuclear Engineering," p. 316 (Prentice-Hall, Inc., New York, 1954)
2. S. Glasstone, M. C. Edlund, "The Elements of Nuclear Reactor Theory" (D. Van Nostrand and Co., New York, 1952)
3. L. W. Nordheim, R. Scalettar, MDDC-42 (1946)
4. J. Codd, C. A. Rennie, AERE R/R 818 (Atomic Energy Research Establishment, Harwell, Eng., 1952)
5. B. Davison, S. Kushneriuk, MT-214 (1946)

Scintillation Counting for Multiple-Tracer Studies

Well counters provide a simple method for measuring two or more radioisotopes in a liquid sample. In a NaI(Tl) counter, Cr^{51} and Fe^{59} γ-rays are separated by pulse-height discrimination. K^{42}-Na^{24} samples require NaI(Tl) and plastic scintillator wells; latter counts K^{42} β-rays but has low γ-ray sensitivity

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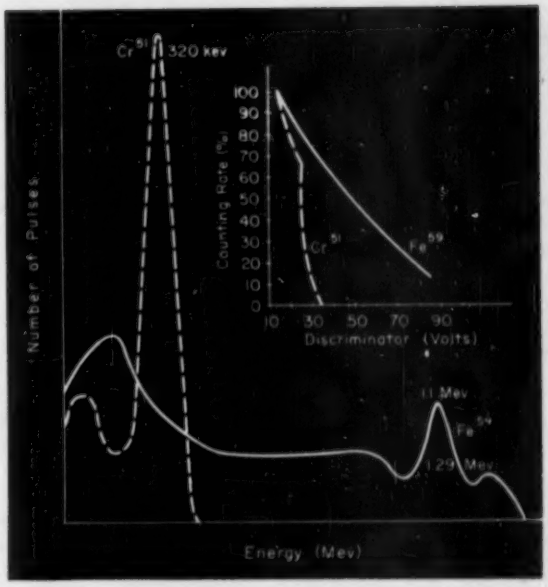

FIG. 1. Pulse-energy spectra and counting rates of Cr^{51} and Fe^{59} γ-rays in NaI(Tl) well

In clinical investigation, it is frequently advantageous to carry out more than one tracer experiment at the same time. Various techniques for the simultaneous use of two radioactive tracer elements have been described recently (*1–3*). If the β- and γ-ray energies of the radioisotope pair within a given sample are similar, it is difficult or even impossible to determine the per cent abundance of each radioisotope at one time. However, if the half-lives of the two radioisotopes differ widely, the time factor can be used for this differentiation. If the energies of their β- and γ-ray emissions differ sufficiently, the mixed isotopes can be differentially counted by using detection instruments with varying absorption characteristics or sensitivities.

The scintillation counter technique described here, employing one or two kinds of scintillation phosphors, can be applied to a great number of radioisotope pairs or possibly to more than two radioactive elements mixed within one sample. The use of well-type scintillation counters with practically 4π geometry requires only one 3-ml liquid sample for each determination. Sample size may be significant in clinical studies if multiple blood samples are required. Furthermore, the multiple-tracer experiments can be conducted with so little radioactivity that the

TABLE 1—Characteristics of Radioisotope Pairs

Radioisotope	*Half-life*	*Maximum β-ray energies (Mev)*	*γ-ray energies (Mev)*
Fe^{59}	46.3 days	1.560 (0.3%) 0.462 (53.9%) 0.271 (45.8%)	0.191 (2.8%) 1.098 (56.7%) 1.289 (43%)
Cr^{51}	27.75 days	*K*-capture, no β-ray emission	0.32 (8%)
K^{42}	12.44 hr	3.58 (80%) 2.04 (20%)	1.51 (20%)
Na^{24}	15.0 hr	1.39 (100%)	1.380 (100%) 2.758 (100%)

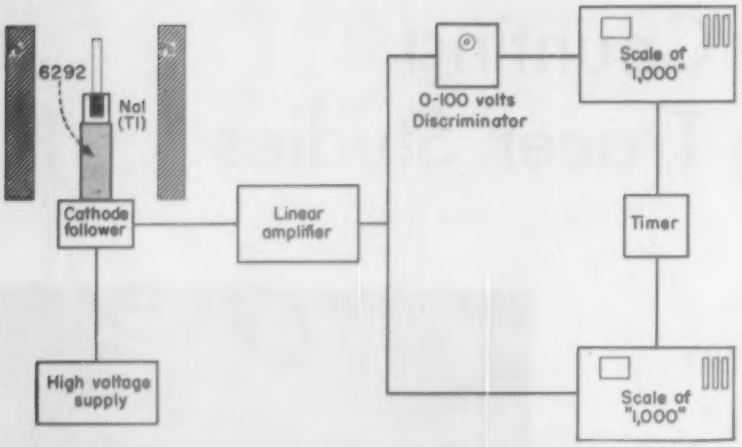

FIG. 2. *Arrangement for simultaneously measuring sample's total number of pulses in NaI(Tl) well and fraction of high-energy pulses produced by one radioisotope in mixture*

dose to the patient may be reduced.

Two pairs of radioisotopes have been studied in particular. Fe^{59} and Cr^{51} are useful in observing the rates of erythrocyte (red blood cell) production and destruction in the same patient. Na^{24} and K^{42} allow the simultaneous determination of the exchangeable sodium and potassium content in a patient. The medical observations will be described elsewhere.

For these two pairs of radioisotopes, the half-lives, the energies of their β- and γ-radiation, and their percentages per disintegration are given in Table 1. It is evident that in both cases no efficient separation can be obtained on the basis of differences in half-lives.

Assay of Cr^{51} and Fe^{59}

For practical purposes, Cr^{51}, which decays by K-capture, has to be counted by its γ-ray emission. Since one γ-ray is emitted in only 8% of all disintegrations, the most efficient γ-ray detector has to be used. Because of the photoelectric absorption of low-energy γ-rays, the NaI(Tl) scintillation counter has a high efficiency for the Cr^{51} γ-rays.

The high-energy Fe^{59} γ-rays are much less effectively absorbed in a NaI(Tl) well counter of standard size. However, since the Fe^{59} γ-rays have more than three times the energy of the Cr^{51} γ-rays, the scintillation pulses from Fe^{59} are distributed over a much wider energy range than those produced by the Cr^{51} γ-rays.

This is shown in two different ways in Fig. 1. The differential-pulse-energy spectra show the pulse-height distribution obtained by photoelectric absorption and Compton interaction of the Cr^{51} and Fe^{59} γ-rays in the NaI(Tl) crystal. The areas under the two curves represent the total counting rates of the two samples.

The insert in Fig. 1 shows the integral discriminator curves for the two γ-ray emitters. The counting rates for Cr^{51} and Fe^{59} have been normalized to 100% for 15-volt discrimination, i.e., when all pulses greater than 15 volts are counted. By increasing the discriminator bias, the Cr^{51} counting rate decreases much more rapidly than that of Fe^{59}. When the Cr^{51} pulses are no longer registered, the Fe^{59} counting rate has dropped to 60% of the total. Therefore, by using an appropriate bias setting, it is possible to determine the relative Fe^{59} content of samples independently of their Cr^{51} content.

By counting the same sample at a low discriminator setting (15 volts), the Cr^{51} content of a mixed sample can be determined. The counting rate due to Fe^{59} γ-rays at the low discriminator setting is obtained from the previous reading at the high setting. The ratio of the Fe^{59} counting rates at the two discriminator settings can be measured accurately with a strong Fe^{59} source containing no Cr^{51}. For example, for Fe^{59}

$$\frac{\text{Counting rate at disc. 15}}{\text{Counting rate at disc. 40}} = \frac{100}{60} = 1.66$$

By multiplying all counting rates obtained with 40-volt discrimination by the factor 1.66, the counting rate due to the Fe^{59} γ-rays at the low discrimination can be determined. Any additional counts measured in a mixed sample must be due to the Cr^{51} γ-rays. It is convenient to obtain the two counting rates simultaneously by using one linear amplifier and two scaling circuits as shown in Fig. 2.

It is obvious that in each case the "net" counting rate has been determined by subtracting the background counting rate, which also changes with the discriminator setting.

Assay of K^{42} and Na^{24}

Since one of the Na^{24} γ-rays has nearly twice the energy of the K^{42} γ-rays (Table 1), it should be possible to apply the previously described technique for their assay. However, the high-energy Na^{24} γ-rays are mainly absorbed by Compton interaction producing a continuous spectrum of rather low-energy pulses (Fig. 3). By comparing the two pulse-energy spectra of the K^{42} and Na^{24} γ-rays, it becomes obvious that about 90% of the Na^{24} pulses would be lost when all the K^{42} pulses are excluded by discrimination. The remaining counting rate is so low that for practical purposes no satisfactory results can be obtained by this method.

If a mixed sample of K^{42} and Na^{24} is placed in a NaI(Tl)-well scintillation counter, which is sensitive to the γ-radiation only, the detection of Na^{24} is favored strongly—Na^{24} emits ten times as many γ-rays per microcurie as K^{42} (see Table 1). Furthermore, by selecting an adequate discriminator bias, this ratio can be increased by a factor of 2-3 without reducing the counting rate excessively. The NaI(Tl) scintillation counter is an efficient detector for Na^{24}, but the problem remains to find an equally efficient detector for K^{42}.

By comparing the maximum β-ray energies of K^{42} and Na^{24} (Table 1), it seems possible that a considerable fraction of the K^{42} β-rays will pass through an absorber thick enough to absorb most of the Na^{24} β-rays. A system of this kind, employing a "dip-counter," has been suggested recently (*3*). However, the large amount of sample required precludes its use for measuring K^{42} content of multiple serum samples in human studies.

It seems advantageous to measure the K^{42} β-rays with the same 3-ml sample that has been used to count the

Na^{24} γ-rays. For this purpose a well-type scintillation counter was developed that is relatively insensitive to the Na^{24} γ-rays but counts those K^{42} β-rays that escape from the liquid sample. As scintillating material, a plastic phosphor* is employed.

The 3-ml sample is placed in a 10-ml Lusteroid test tube to reduce the absorption of the K^{42} β-rays. The test tube has a 0.5-in. diameter and only a small fraction of Na^{24} β-rays emitted near the wall of the plastic test tube can enter the scintillation counter. (An additional absorber has to be employed when this kind of sample is placed into the NaI(Tl) well counter to eliminate the K^{42} β-rays.)

In the plastic-well scintillation counter, the counting rate per microcurie of K^{42} is at least twice that of Na^{24}. This ratio, however, can be increased as discussed later. The plastic-well scintillation counter has proved to be a sufficiently sensitive detector for K^{42} in the presence of Na^{24}.

Evaluation of sample measurements. The counting rate of a given sample containing a mixture of Na^{24} and K^{42} will be called C_1 for the NaI(Tl) counter and C_2 for the plastic scintillator. A pure Na^{24} standard will have counting rates n_1 and n_2 in the two counters, and a pure K^{42} standard, counting rates k_1 and k_2. The sensitivity of the NaI(Tl) counter to Na^{24} will generally be greater than that of the plastic scintillator; therefore, $n_1 > n_2$. For K^{42}, the plastic scintillator is the more sensitive one; therefore, $k_2 > k_1$. Thus, the relative sensitivities of the two systems for Na^{24} and K^{42} are

$$N = n_2/n_1 < 1 \text{ and } K = k_1/k_2 < 1$$

The two counting rates of the mixed sample can be expressed as

$$C_1 = n_1X + k_1Y$$
$$C_2 = n_2X + k_2Y$$

where X and Y are the unknown amounts of Na^{24} and K^{42} present in the sample, both expressed as a fraction of their respective standards. Since X and Y are the only unknowns in the two equations, they can be solved easily.

$$C_1 = n_1X + k_2KY$$
$$C_2 = n_1NX + k_2Y$$
$$X = \frac{C_1 - KC_2}{n_1(1 - NK)},\quad Y = \frac{C_2 - NC_1}{k_2(1 - NK)}$$

* Pilot Scintillator B, Pilot Chemicals, Inc., Waltham, Mass.

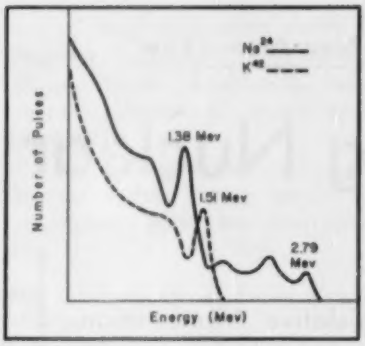

FIG. 3. Spectra of K^{42} and Na^{24} γ-rays in NaI(Tl) crystal

If the NaI(Tl) counter were insensitive to K^{42}, k_1 would be zero and therefore $K = 0$. From the above equation it would follow $X = C_1/n_1$, which is the Na^{24}-sample counting rate divided by the counting rate of the standard.

In actual practice, the relative contribution of Na^{24} and K^{42} to the combined sample count depends on the size of the dose of each isotope and the biological sample that is obtained.

By using strong standard solutions, the ratio of the counting sensitivities N and K can be accurately determined. They depend on sample size, dimensions of the two scintillation counters, pulse amplification, and discriminator choice. For a given set-up they are constant and will not change with the decay of the samples. Appropriate decay corrections have to be applied to the observed counting rates of samples and standards.

Gamma-ray sensitivity of NaI(Tl) and plastic-well counters. Measurements have been taken with a "standard" NaI(Tl) well scintillation crystal† of 1¾-in. diameter, 2-in. height. The inside of the well is ⅝-in. in diameter and 1½ in. deep. The dimensions of the plastic-phosphor-well counter were about the same as those of the NaI(Tl) crystal. The interior well surface of the plastic phosphor was covered with black Scotch tape as a thin light shield.

The production of secondary electrons by the K^{42} and Na^{24} γ-rays passing through the scintillator walls could be calculated accurately if their path lengths were known. On the other hand, it is difficult to measure the total number of pulses produced by a calibrated sample, since a certain fraction of low-energy pulses will not be detected. By comparing calculated and experimental data, the sensitivity of the NaI(Tl) well counter per γ-ray from either K^{42} or Na^{24} was about 20%. This corresponds to nearly 4π geometry and an average path length in NaI of 2 cm for the high-energy γ-rays.

For the plastic scintillator, the γ-ray sensitivity was about one third that of NaI(Tl). This is mainly due to a difference in density that is close to unity for the plastic and 3.67 for NaI.

In Table 2, the approximate γ-ray counting efficiencies (per cent pulses per disintegration) are given. Since Na^{24} emits two γ-rays per disintegration, the γ-ray counting efficiency in the plastic phosphor is still rather high. It can be further reduced by using a plastic well scintillator with thinner walls.

The β-ray efficiency of the plastic phosphor is unity, since all β-rays that enter it are counted. The actual per cent of all β-rays that get into the plastic depends on the sample volume and shape and on the amount of absorber between sample and plastic phosphor. The data given in Table 2 for the β-ray efficiencies have been obtained with the 3-ml sample in the Lusteroid test tube and a layer of Scotch tape of approximately 25-mg/cm² thickness. It can be seen from Table 2 that the plastic scintillator is rather efficient for K^{42} while the NaI(Tl) counter is very efficient for Na^{24}.

† Harshaw Chemical Co., Cleveland 6, Ohio.

TABLE 2—Counting Efficiencies for 3-ml Sample in Well-Type Scintillation Counter

	Efficiency (%/disintegration)			
	NaI(Tl)		*Plastic*	
Isotope	*β-rays*	*γ-rays*	*β-rays*	*γ-rays*
Na^{24}	0	40%	7%	13%
K^{42}	0	4%	30%	1%

BIBLIOGRAPHY

1. J. F. Tait, E. S. Williams, NUCLEONICS **10**, No. 12, 47 (1952)
2. B. A. Burrows, G. J. Hine, J. F. Ross, *Clin. Research Proc.* **2**, 81 (1954)
3. C. V. Robinson, W. L. Arons, A. K. Solomon, *J. Clin. Invest.* **34**, 134 (1955)

Part II of "The Meaning of the New Atomic Law"

Licensing Nuclear Facilities

Mr. Cole examines the legislative frame upon which he believes an atomic industry can be built. Most of the discussion is based on the following provisions of chapter 10 of the law:

"Sec. 101. LICENSE REQUIRED.—*It shall be unlawful, except as provided in section 91, for any person within the United States to transfer or receive in interstate commerce, manufacture, produce, transfer, acquire, possess, import, or export any utilization or production facility except under and in accordance with a license issued by the Commission pursuant to section 103 and 104.*

"Sec. 102. FINDING OF PRACTICAL VALUE.—*Whenever the Commission has made a finding in writing that any type of utilization or production facility has been sufficiently developed to be of practical value for industrial or commercial purposes, the Commission may thereafter issue licenses for such type of facility pursuant to section 103.*

"Sec. 103.—COMMERCIAL LICENSES.—*a. Subsequent to a finding by the Commission as required in section 102, the Commission may issue licenses to transfer or receive in interstate commerce, manufacture, produce, transfer, acquire, possess, import, or export under the terms of an agreement for cooperation arranged pursuant to section 123, such type of utilization or production facility . . .*

"Sec. 104. MEDICAL THERAPY AND RESEARCH AND DEVELOPMENT.—*"a. The Commission is authorized to issue licenses to persons applying therefor for utilization facilities for use in medical therapy . . .*

"b. The Commission is authorized to issue licenses to persons applying therefor for utilization and production facilities involved in the conduct of research and development activities leading to the demonstration of the practical value of such facilities for industrial or commercial purposes . . .

"c. The Commission is authorized to issue licenses to persons applying therefor for utilization and production facilities useful in the conduct of research and development activities of the types specified in section 31 and which are not facilities of the type specified in subsection 104 b . . .

"Sec. 105. ANTITRUST PROVISION.— . . .

"Sec. 106. CLASSES OF FACILITIES.—*The Commission may—a. group the facilities licensed either under section 103 or under section 104 into classes which may include either production or utilization facilities or both, upon the basis of the similarity of operating and technical characteristics of the facilities; . . .*

"Sec. 107. OPERATORS' LICENSES.—*The Commission shall—a. prescribe uniform conditions for licensing individuals as operators of any of the various classes of production and utilization facilities licensed in this Act; . . .*

By Rep. W. STERLING COLE (R., N.Y.)
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Joint Committee on Atomic Energy
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IN REDRAFTING the nation's organic atomic law last year, a critical policy problem confronting the Joint Committee on Atomic Energy was this: How could the legal basis be laid for transition of this promising industrial field from strict government monopoly, predicated exclusively upon the Constitutional power of providing for the common defense and security, into a condition more in accord with our traditional system of free competitive enterprise, and at the same time maintain the necessary safeguards against hazards to public health and national security.

In counterpoint was the necessity in our democratic republic of assuring equal opportunity to all, and, in a field so cloaked with secrecy, giving the fullest play possible to the protections of due process of law, which forms the bulwark of our system of government.

Upon the success with which these fulcral issues are met depends the speed and fullness with which private companies are enabled to enter the atomic field, bringing to bear upon its development the proved abilities of free and competitive enterprise. Most will agree, I believe, that the new law, in the main, is a realistic and fully adequate legislative frame upon which an atomic industry can be built and can flourish. Whether that industry is built well and quickly now depends upon actions of the Atomic Energy Commission, which will block-in with regulation and order the outlines of control contained in our legislative action, and equally upon private companies and persons who will invest their talents, energies and money in developing the industry under Commission regulations and license.

Basically, the new law establishes three principal points of Federal control of atomic energy: information, materials, and facilities. That is to say, the Federal Government is vested with powers (a) to determine what knowledge must be held secret and under what circumstances that secret information may be disseminated or used; (b) to restrict the possession, use or transfer of those materials vitally important or involved in the field either by reason of public health or national security; and (c) to control the building, possession, use and transfer of facilities for production or utilization of atomic energy or of particularly sensitive materials that, in the law, are called special nuclear materials.

The law also contains secondary control points: It authorizes the Commission to establish health and safety regulations; it requires the Commission to establish conditions for granting of licenses to individuals who operate production or utilization facilities; and it retains for the Government a residual but preemptive control upon new patents issued on applications filed in nonmilitary areas until 1959.

Facilities Controlled by License

Basic to an understanding of the control-of-facilities features of the new law is the concept that the new industry should be governed by licenses rather than by contracts. It was felt that an independent industry, using its own capital, would rise to make the fullest uses of atomic energy in peacetime applications if it were not subject to the dead hand of Government contracting, with its inherent retention of direction and scope to a Federal bureaucracy. Of course it was recognized that the Government would, for its own purposes, continue to utilize a system of contracts and subcontracts. But no system of Government contracting has yet been devised that will substitute for the competitive force toward progress that inheres to a system of private venture.

It was also clear to us, however, that the efforts of free enterprise, using its own resources and money, are by themselves inadequate to achieve the speediest possible attack on the goal of peacetime atomic power. Therefore the law encourages flourishing research and development programs under both Government and private sponsorhips.

In determining the scope of control to be vested in the Commission's licensing authority, it became immediately apparent that, because of the diversity of possible uses of nuclear reactors, the Commission's control should be over the reactor as a nuclear device, leaving specific applications of reactors subject to regulation by the concerned agency. Thus, a reactor for use in an aircraft, for example, would be licensed by the Commission as a source of power, governed by interests of common defense and public health and safety, but operation of the aircraft would be subject to normal authority of the Civil Aeronautics Board, or other agencies having authority over airplanes.

" . . . the new industry should be governed by licenses rather than by contracts . . . no system of government has yet been devised that will substitute for the competitive force towards progress that inheres to a system of private venture."

" . . . the Commission control should be over the reactor as a nuclear device, leaving specific applications of reactors subject to regulation by the concerned agency."

Similarly it was thought that a reactor powering a locomotive should be regulated by the Atomic Energy Commission only as a source of power using atomic energy, in the interests of the common defense and to protect the public health and safety. Control over operation of the locomotive powered by a reactor should be left to the Interstate Commerce Commission or the state public utility or railroad commission having jurisdiction. It was likewise thought that when a reactor is used to power a plant generating electricity for public utility purposes, the reactor should be regulated by the Atomic Energy Commission only in the interests of common defense and security and to protect the health and safety. The generation and sale of electricity from the atomic power should be regulated by that agency, state or Federal, that otherwise has jurisdiction over the generation, transmittal, and sale of electricity.

Kinds of Facilities

Reactors have been built and can be built in the future to produce materials of value, especially special nuclear materials. Many of the Commission's reactors now are designed essentially toward the production of such materials and not toward the production of power. There are many types of facilities in addition to reactors that are involved in the production of special nuclear materials, such as the gaseous diffusion plants, or facilities for the chemical treatment of the materials coming out of reactors or for the manufacture of fuel rods containing special nuclear material.

It was the hope of the Congress that private industry would enter in all of these phases of the atomic energy field. The licensing provisions are aimed at permitting an independent industry to grow in all of them.

In the new law, a reactor utilizing special nuclear material to produce power is termed a "utilization facility," while a facility engaged in any portion of the production of special nuclear material is a "production facility."

There is no known reactor that does not combine some of the features of both a production facility and utilization facility. That is, there is no known reactor not producing special nuclear material at the same time that it is burning up special nuclear material. For simplicity and clarity the Commission, in Section 106, is permitted to group production and utilization facilities together for licensing purposes.

The Commission has been authorized, then, to categorize the type of facility according to its scientific characteristics and to issue licenses and regulations on the basis of the similarity of operating and technical characteristics. Thus, for instance, the Commission will be able to issue one type of regulation for an airplane reactor, another type of regulation for a water-cooled power reactor, and a different type of regulation for a homogenous reactor or a breeder reactor, each depending upon the implication of the specific type of reactor to the common defense or to public health. If the same type of reactor can be used both for power production and for production of special nuclear materials, it is contem-

plated that one kind of regulation should apply to licenses for either use, unless there are strong differences in the performance characteristics of the reactor when used for different purposes.

The Commission has the basic responsibility of determining what are production facilities and what are utilization facilities under the new Act. In each instance the Commission has the positive duty of declaring facilities to be production facilities or utilization facilities where their operation involves such quantities of special nuclear material as to be significant to the common defense and security or where their operation can affect the health and safety of the public. This task is imposed on the Commission because of its special technical knowledge and its ability to gage the extent to which the technical operations of the facility require such regulation.

Commercial Plants

The drafters of the new law recognized that before we can have reactors capable of being built and used on a commercial basis there are many technical problems to be solved. As of this writing, no production or utilization facility has been determined to be of practical value, in the sense of Section 102. Therefore in so far as reactors are concerned, the first licenses will be for research and development. One example of a production facility that appears eligible for early determination of practical value is a facility in which fuel rods containing special nuclear material are manufactured. The techniques used closely resemble established metallurgical operations, and thus their commercial significance is more readily demonstrable.

The law permits licensing of research and development reactors of two general kinds. (Medical therapy reactors are considered separately, since their use is not for the extension of reactor technology or the study of nuclear processes, but rather for the application of atomic energy to medical study, diagnosis, and treatment).

The first type of research and development reactor is one to be used primarily for experimental purposes, with no intention of turning its operation to other than research purposes. Such a reactor, licensed under Section 104c, might be an experimental or materials testing reactor. It would produce no commercially usable power, and the neutron flux within the reactor would be used to bombard various materials to study their characteristics under neutron or other irradiation. This type of license could also be issued for a "zero-power" reactor, such as is frequently used in testing reactor components and in establishing the final specifications of a proposed reactor.

The second kind of research and development reactor is one directed toward proving the practical value of that reactor type. It would be licensed under Section 104b. Such a reactor could be an experimental breeder reactor, or an experimental pressurized water reactor, which still require considerable development and operation experience before it would be possible to determine the commercial attractiveness or practical value of those particular reactor types.

As soon as sufficient work has been done on any type of facility to allow the Commission to make a finding under Section 102 that that type of facility is of practical value, the Commission must thereafter issue licenses for that type of facility on a nonexclusive industry-wide basis. This statutory basis for the regulation of the atomic energy field is designed to parallel in the atomic energy field the licensing philosophy of the Federal Communications Commission in the radio field. In that field both f-m radio and television were developed under rather flexible experimental licenses until they were proved to be of commercial value. When they were found to have reached this stage, the main body of licenses were then declared to be commercial licenses and the facilities were used for profit on a commercial basis.

The Atomic Energy Commission in issuing regulations for research and development reactors is specifically directed to impose only that amount of regulation essential to provide for the common defense and security and protect the health and safety of the public.

In fostering a new industry, still in the creative stage, the Commission is authorized to be less stringent in its regulation than it would be in the commercial stage, to provide the flexibility so vital to a continued research. It must be possible for a research and development facility to be taken down and rebuilt incorporating new ideas with the minimum of red tape. Also, a reactor being used to prove that its type is commercially practical should not be under the stringent licensing requirements of full commercial operation where the facility is generally operated from one year's end to another without material change.

On the other hand, a demonstration facility does not demand as much flexibility as one for more basic types of research. The Commission should issue those rules for the operation of a demonstration facility, under Sec. 104b, that would not be widely divergent from the rules the Commission might reasonably expect to impose if that type of facility were found to be of practical value. Admittedly, the Commission is required to do some crystal-ball gazing, but the hope is that it will evolve a type of regulation reasonably harmonious with regulations that would be imposed on a commercially operated facility of the same type.

The main desire of the Congress in drafting these licensing requirements was to permit the Commission to exercise discretion in regulating research and development facilities, but still maintain necessary regulation of facilities used for commercial purposes. The authority of the Commission to license the individuals who manipulate the controls of licensed facilities is an important element in the exercise of this discretion. The Commission can thus maintain a check upon persons who will control a potentially hazardous device. Each reactor presently built is operated from a console. It was the thought that the personnel who operate those consoles should always have an educational background and training such as to assure the safe operation of the reactor just as is the case with pilots of aircraft. Personnel such as shift supervisors who might direct the person at the console are not required to be licensed, unless they would have to perform operating duties in the event of an emergency.

Licenses for all facilities are made subject to the right of the Federal

"The Atomic Energy Commission in issuing regulations for research and development reactors is specifically directed to impose only that amount of regulation [that is] essential . . . "

"It is our hope that the Atomic Energy Commission would never become involved in a 'color television' decision."

government in times of national emergency to withdraw the special nuclear material or to operate the facilities as the Federal government may decide in the national interests.

Although there is little in the Act specifically on the point, it is the hope of the drafters of the Act that the selection of various technological routes to commercial facilities be resolved in the market place, and not in the Commission. It is our hope that the Atomic Energy Commission would never become involved in a "color television" decision.*

Due Process

The procedures for obtaining licenses are prescribed in a series of sections in Chapter 16. The basic thought in the chapter is to make the procedures of the Administrative Procedure Act applicable just as far as possible. Because of the requirements of security, the public features of these procedures cannot always be followed. The Commission is directed to establish procedures that assure the protection of secret information involved but parallel as closely as possible the normal procedures. Thus if public announcement would otherwise be required, but secrecy forbids the widespread dissemination of the information, it is expected that the Commission will distribute it to all those who would be permitted to receive similar information. For instance, a regulation proposed to be issued on the control of a specific type of reactor that cannot be publicized, should be disseminated to those who are cleared to receive information of similar sensitivity and all other persons who can meet security clearance standards and who have a legitimate interest.

The Commission is required to establish by rule the type of information to be furnished by the applicants for a license. This will necessarily depend on both the type of facility involved and the particular status of the applicant. The Commission is also given power to prescribe the extent of the technical information it will require prior to issuance of a license for the construction and operation of facilities. This information will also be used as a basis for determining permissible variation in operation authorized in the original license without requiring further Commission sanction. One of the items on which information might be required in license applications is the financial qualifications of the applicant since construction or operation of a reactor under financial distress might induce the owner to take dangerous shortcuts, leading to hazardous conditions.

If the Commission finds that an application for a reactor that will generate commercial electricity has a likelihood of maturing into a license, it is required to publish notice of the application in the Federal Register and to give special notice to the local governments and to any regulatory agency having jurisdiction. This requirement gives to others who might be interested in constructing and operating a reactor in the same geographic area an opportunity to be considered by the Commission at the same time, and also gives the regulatory agencies involved an opportunity to present their views. While the Commission issues licenses only for the reactor portion of the generating facilities, the regulatory agencies may appear and testify, since the ability of the applicant to abide by the rules of the applicable regulatory agency will in part determine the financial and other qualifications of such an applicant. In the event that there is limited opportunity for a license for such a facility—that is, in case there is not enough nuclear fuel to meet demand—the statute requires that preference be given to applications from high-cost power areas, and within those areas to public bodies and cooperatives.

To be sure that the Commission at all times knows who owns and operates each reactor, licenses are made inalienable except with Commission consent. To give the applicant a definite ruling on his plans and qualifications so he can proceed with the financial backing and construction of a facility, the Commission is authorized to issue construction permits that will automatically ripen into licenses on satisfactory completion of the facility.

The statute also provides for the revocation of a license in the event that the Commission finds infraction of its rules, or if the Commission later finds any reason that would have warranted it not having issued the license in the first instance. The Commission is, however, required to give the license holder opportunity to remedy the defect, if it is remediable.

In cases of extreme importance, the Commission is permitted to move swiftly without notification of violation and before hearing. It is expected that this power would be used only in case the Commission found the method of operation of a facility was such as to cause immediate danger to the public health and safety, or an immediate detriment to the national defense. Thus if the licensee were found to be using the facility to construct atomic weapons, the Commission could take action to halt the operation without going through prolonged administrative procedures.

On the other hand, the Commission itself is authorized to take over and continue running facilities after revoking a license, if cessation of operation would, for instance, leave a city or an industry without electric power, or would deprive the Federal government of essential materials.

However, all final rights in and to the license, whether arising out of application for or revocation of license or out of the issuance of rules and regulations controlling licenses, would be determined only after a hearing, if one is requested.

Provision is made for an appeal to the courts from the result of any such a hearing, in accordance with the usual methods of appeal from determinations of regulatory agencies.

Thus it can be seen that the Congress, in erecting the regulatory structure for a new industry, sought to provide as many as possible of the normal safe-guards of due process of law without, at the same time, adversely affecting the common defense and security.

Just as more and more information on atomic weapons has been made public, so it is anticipated that more and more information on nuclear reactors will be made public. It was the intention of Congress that the new industry be so established that, as the veils of secrecy are withdrawn from the field, the normal regulatory procedures will already underlie the field and be made more and more effective. END

* This was a case where an administrative decision attempted to set the course of technological advance.

Measuring High Doses by Absorption Changes in Glass

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Changes in optical density of glass measure doses up to 2×10^6 rep with 5% accuracy independent of dose rate. Dosimeter is convenient ($1 \times 1 \times 0.3$-cm plate) and rugged. Standardizing measurement time or heat treatment solves problem of fading

LARGE-SCALE USE of massive gamma-ray or electron-beam doses in food and drug sterilization has created a need for a more convenient dosimeter than present chemical systems (*1*). Radiation-induced changes in absorption, luminescence, and other properties of solids have been used to measure comparatively low doses of ionizing radiations (*2–4*), but little attention has been given to high-doses (*5*). The excellent personnel-dosimeter performance of silver-activated phosphate glass (*4*), suggested that it be studied first. For high doses, radiation-induced absorption changes in this glass are large enough to measure dose directly; hence this property was examined rather than the radiophotoluminescence used in the personnel dosimeter.

The base glass used in dosimetry has the following composition in weight per cent: 50% $Al(PO_3)_3$, 25% $Ba(PO_3)_2$, and 25% KPO_3. To this base glass approximately 8% by weight of $AgPO_3$ is added to produce its radiophotoluminescence. The glass has been manufactured in commercial quantities by several companies, and its properties controlled.

Absorption spectra of unactivated and silver-activated glass are sensitive to radiation as shown in Fig. 1. This effect was studied as a function of dose, dose rate, type of radiation, and time following exposure.

Dose Dependence

Polished plates of the glasses approximately 0.5 mm thick and 1×1 cm square were prepared. Doses of Co^{60} and, sometimes, Ta^{182} radiation from 10^2 to 3×10^5 rep were delivered to two plates of each type by the fission products utilization group at Brookhaven National Laboratory under the direction of B. Manowitz and O. Kuhl. Dose rate for exposures up to and including 3×10^4 rep was 240,000 rep/hr. Dose rate for exposures between 10^5 and 3×10^5 rep was 575,000 rep/hr as determined by chemical dosimetry and 600,000 rep/hr as determined by an ion chamber. The chemical-dosimetry dose rate was used to compute exposure time.

A parallel series of exposures from 10^3 to about 10^5 rep of Co^{60} were given to two plates of each type at the Department of Food Technology, Massachusetts Institute of Technology, under the direction of S. A. Goldblith. Doses were calculated from time of irradiation, position of plates in the

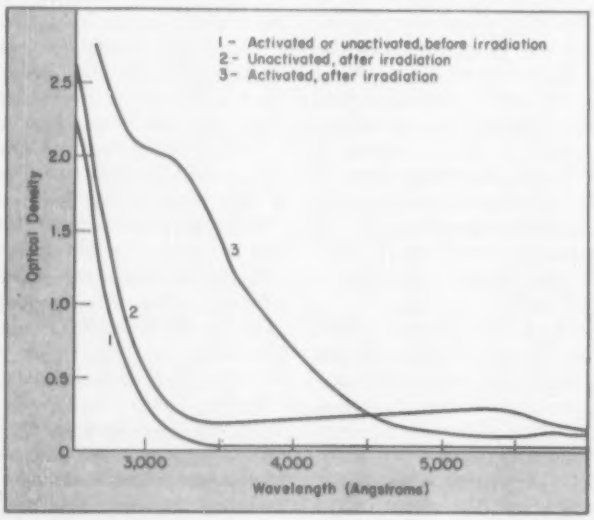


FIG. 1. Absorption spectra of 0.5-mm-thick samples. Measurements on thicker samples of unactivated glass show that its radiation-induced absorption is principally in two broad bands peaking at 4,300 Å and 5,200 Å, making it purple. Activated glass develops new band, peaking at 3,200 Å and spreading into the visible, making it yellow

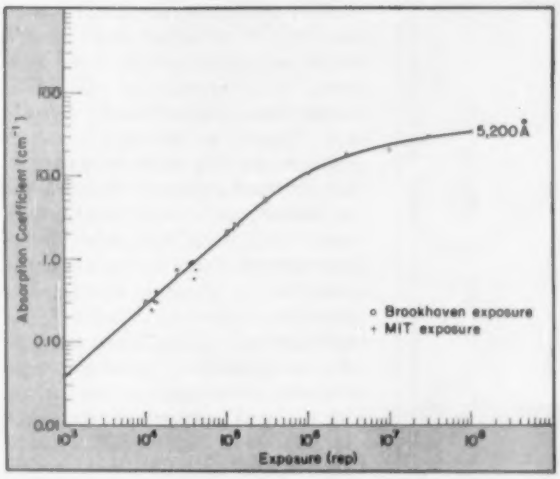


FIG. 2. Dose dependence of absorption of silver-activated glass. Note good agreement between Brookhaven and M. I. T.

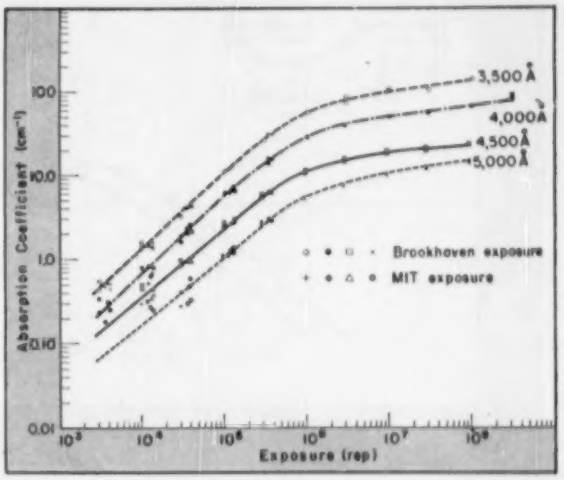


FIG. 3. Dose dependence of absorption of unactivated glass as measured at 5,200 Å

source, and the ~70,000-rep/hr dose rate, previously determined calorimetrically (*6*). The Brookhaven and M.I.T. dosages will be shown to agree.

Approximately one month after the gamma-ray exposure, optical transmission measurements were made. Transmission data were converted to absorption constants to render results independent of glass thickness. Corrections were applied for absorption and reflection losses in unirradiated plates. Typical absorption data are given in Figs. 2 and 3. Response is essentially linear up to 10^5 rep, where saturation effects appear. Sensitivity (i.e., change in absorption coefficient per unit dose) drops to undesirably low values at about 2×10^6 rep. Modification of composition and synthesis of new glasses are being investigated in an attempt to develop a dosimeter useful to 10^7 rep or higher.

Sensitivity also decreases with increasing wavelength, as shown in Fig. 2 for the silver-activated glass. The wavelength variation of sensitivity allows one to standardize on one thickness of glass and yet obtain convenient optical density values for doses ranging from about 5×10^3 rep up to the limit of usefulness of the glass. For low doses, adequate optical-density changes are observed when the measurements are made at 3,500 Å on a 3-mm-thick specimen. For higher doses the optical density at 3,500 Å is much too high for convenient measurement, and the dose is determined from measurement at longer wavelength.

Dose-Rate Dependence

Dose rate (rep/hr)	*Dose (rep)*	*Absorption constant (cm^{-1}) 3,500 Å*	*Sensitivity ($cm^{-1}/10^6 r$) 3,500 Å*	*Procedure**
575,000†	104,000	10.05	9.66	A
575,000†	104,000	9.13	8.78	B
225,000	102,000	10.72	10.51	A
225,000	102,000	10.22	10.02	B
780,000‡	89,500	9.88	11.04	A
780,000‡	89,500	9.62	10.75	B
10,000 (Ta^{182})	101,000	11.90	11.78	A
10,000 (Ta^{182})	101,000	11.30	11.19	B
575,000	105,550	11.41	10.82	From original series of exposures illustrated in Fig. 2
575,000	105,500	11.31	10.72	
		Average	10.5 ± 0.6	

* Procedure A: Glass dry, taped to outside of chemical dosimeter. Procedure B: Glass wet, immersed in chemical-dosimeter solution.
† Chemical dosimetry (ceric sulfate); ion chamber gave 600,000 r/hr.
‡ Chemical dosimetry (ceric sulfate; ion chamber gave 800,000 r/hr.

Dose-Rate Dependence

Dose-rate dependence was studied by exposing a set of plates at Brookhaven to a total dose of approximately 10^5 rep at dose rates varying from 10^4 rep/hr to 7.8×10^5 rep/hr. Results of measurements at 3,500 Å are shown in the table (left). There appears to be no significant effect of dose rate over the dose range investigated. Similar experiments with Co^{60} and fuel-element radiation (at the Materials Testing Reactor) show no dependence on dose rate at rates above 10^7 rep/hr.

Energy Dependence

The energy dependence of the radiophotoluminescence response of silver-activated glass has been reported earlier (*4*). The sensitivity is energy-independent from 200 kev to Co^{60} energies; below 200 kev, however, the

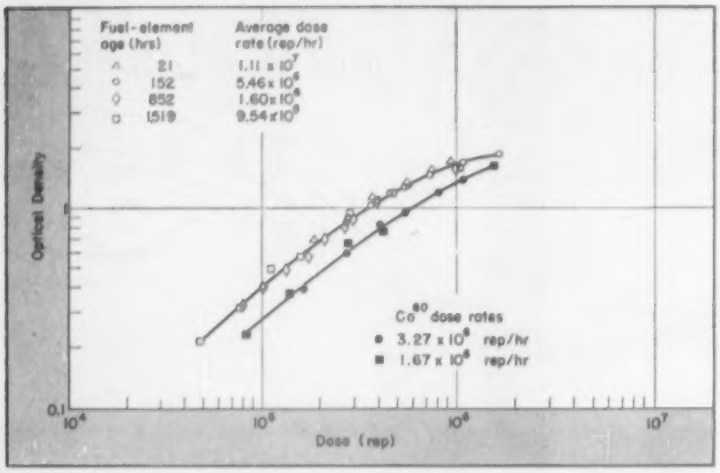


FIG. 4. Change in optical density of silver-activated glass after irradiation by fuel elements and by Co^{60}

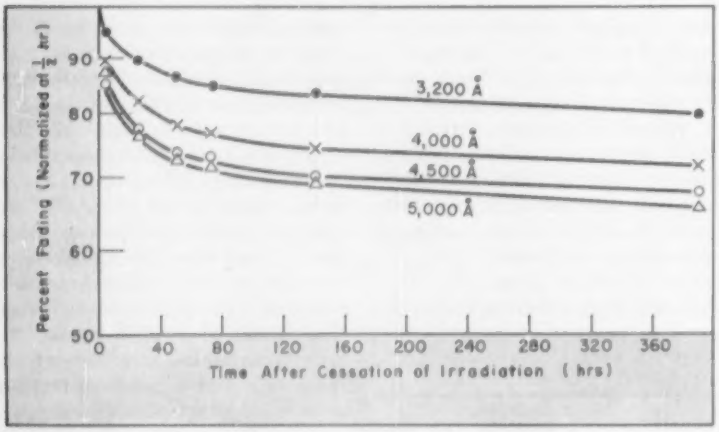


FIG. 5. Fading of silver-activated glass. This specimen received a 5.1×10^4-rep Co^{60} dose in 6 minutes, then it was stored in the dark at room temperature

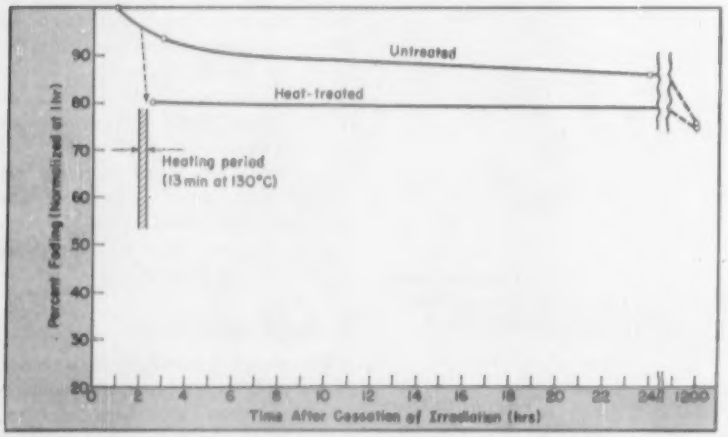


FIG. 6. Effect of heat treatment on fading of silver-activated glass. Absorption measurements were at 3,500 Å following a 1-hr exposure to a 2,500-c Co^{60} source

sensitivity increases, becoming 18 times that for Co^{60} at about 65 kev. Although no explicit studies have been made, it is certain that absorption changes have similar energy dependence. This being the case, question may arise as to the applicability of the glass where low-energy contributions are present, as in food sterilization, where considerable low-energy radiation can be scattered by the irradiated product itself. However, such applications offer no particular difficulty since, once calibrated in the geometry of concern, the glass serves as an adequate dosimeter for subsequent irradiations with the same geometry and source.

Fuel-Element Dosimetry

The applicability of silver-activated glass in spent-fuel-element dosimetry has also been investigated. Fuel elements have a very broad gamma-ray energy spectrum that is also time dependent because of the complicated decay of fission products. Exposures with Materials-Testing-Reactor fuel elements were made at varying times after reactor shutdown to ascertain the response of silver-activated glass to different aged elements. Exposures were carried out in water in the MTR canal. Doses delivered to glass plates were based on ceric-sulfate dosimetry (*1*) using a cerium yield of 2.58 μM/l/1,000 rep. The glass plates used were 121 ± ½ mil thick (approximately 3 mm); hence all measurements were made at 5,000 Å, rather than at shorter wavelengths where the glass is more sensitive, to obtain favorable optical densities in the high-rate radiation fields. Densities were measured ½ hr after irradiation. The results are shown in Fig. 4.

The curve depicting the fuel-element irradiations shows clearly that glass response is dependent only on dose, and is independent both of fuel-element age from 21 to 1,519 hr and of dose-rate up to rates exceeding 10^7 rep/hr. The Co^{60} curve shows the same qualitative behavior; quantitatively, however, optical density changes for the fuel-element-exposed glass is approximately 30% greater than at corresponding Co^{60} doses. Perhaps this difference can be explained by the greater proportion of low-energy radiation from fuel-elements and the known increased sensitivity of the glass below 200 kev. It can also be inferred that the gammas below 200 kev constituted

a small and constant fraction of the total spectrum.

Fading

Fading of coloration of irradiated crystals and glasses in storage is a well-known phenomenon. The influence of this effect on the measurements reported in the foregoing sections was minimized by standardizing the time at which optical measurements were made in each series of experiments.

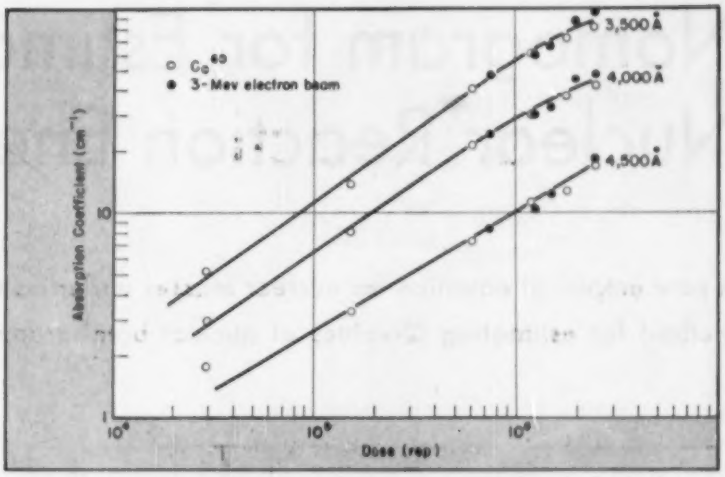
Typical fading of a silver-activated glass plate at 5,000 Å, shown in Fig. 5, is at a rate that is greatest immediately following irradiation and decreases at longer times. These results also show that rate and magnitude of fading are spectrally dependent; the most pronounced fading occurs at approximately 4,500 Å with increased stability of coloration on either side.*

Since fading is appreciable, means are required to prevent its interference with the usefulness of the glass as a dosimeter. Several solutions are available. First, one can standardize so that all optical density readings are made at a given time following exposure. In this way the same amount of fading occurs in all exposures and hence its net effect is eliminated. The standard time for making optical-density readings should be long after exposure to minimize errors introduced by fading during different length exposures. If it is desired to standardize at a time shortly after exposure, corrections must be applied for different length exposures. The method of making such a correction is illustrated in a separate paper (7).

A second approach to fading requires the preparation of fading curves at each wavelength so as to be able to correct to the time of measurement upon which the calibration curve is based. This factor of reduction could then be applied to glass plates read weeks or even months following exposure; the dose would follow from the original calibration curve. This method has the added advantage that glass plates once read could be reread at any subsequent time to verify a former dose determination. Once again, it is advisable to standardize calibration measurements of optical density at time intervals considerably larger than the exposure times. This then eliminates added correction for fading during exposure.

This dosimeter is most easily used if fading is dose-independent. Preliminary information indicates that there is at most a small dose dependence of fading over the useful dose range of the glass. This information, however, is not conclusive; additional work is required. This fading-curve method continues to be applicable to the fading problem; the dose-independent situation merely is simpler.

A third method of treating fading is suggested by the fact that early fading is largest and most rapid, indicating that some unstable centers are involved in the coloration. It appeared possible, therefore, to accelerate the disappearance of these centers by short, mild heating without destroying more stable color centers that give long-lasting coloration. An exposed plate was heated for 13 min at 130° C. Previous experience showed that this temperature would not directly destroy stable color centers. After heat treatment, the absorption of the samples was measured as a function of time. The results are illustrated in Fig. 6. It can be seen from this curve that this short heat treatment does accelerate fading of unstable centers while leaving more permanent centers essentially undisturbed. In a few minutes a stable end result is achieved that would normally require at least a day at room temperature. It has also been shown that length of heating is not critical. Most of the unstable centers are bleached after 5 min at 130° C, and a 30-min heating time produces only 5% more fading. Measurement of heat-treated samples after 50 days showed that further fading over this period amounted to no more than 5% of the absorption determined immediately after heat treatment. It appears possible, at a small sacrifice in sensitivity, to eliminate the fading problem entirely by a preliminary mild heat treatment before the optical density of the glass is measured. Further studies are underway to determine if this procedure can be reliably employed.



ELECTRON-BEAM DOSIMETRY: Data on dosimetry of electron beams with silver-activated glass, taken at M. I. T. by Samuel A. Goldblith, show that dosimeter works well for high-energy electrons

* * *

In addition to those mentioned in the article, we wish to thank Howard Watanabe and Darrow Reeder of the MTR staff for their assistance in fuel-element studies, Robert J. Ginther and Russell D. Kirk of NRL for their many contributions in the Co⁶⁰ studies, and William E. Price and Norwood G. Long, also of NRL, for data on the spectral dependence of fading shown in Fig. 5.

BIBLIOGRAPHY

1. J. Weiss, NUCLEONICS, **10**, No. 7, 28 (1952)
2. H. Friedman, C. P. Glover, NUCLEONICS **10**, No. 6, 24 (1952)
3. F. Daniels, in "Chemistry and Physics of Radiation Dosimetry," Part I, p. 148 (Army Chemical Center, Maryland, 1950)
4. J. H. Schulman, W. Shurcliff, R. J. Ginther, F. H. Attix, NUCLEONICS **11**, No. 10, 52 (1953)
5. E. J. Henley, A. Miller, NUCLEONICS **9**, No. 6, 62 (1951)
6. B. Davison, S. A. Goldblith, B. E. Proctor, M. Karel, B. Kan, C. J. Bates, NUCLEONICS **11**, No. 7, 22 (1953)
7. H. Rabin, W. E. Price, NUCLEONICS **13**, No. 3, (1955) to be published

* More extensive data by F. Martin of Corning Glass Works show a peak in fading at approximately 4,500 Å with decreased fading in going from 4,500 Å to 3,500 Å and from 4,500 Å to 7,000 Å.

Nomogram for Estimating Nuclear Reaction Energies

A new empirical equation for nuclear masses underlies this method for estimating Q-values of nuclear bombardment reactions

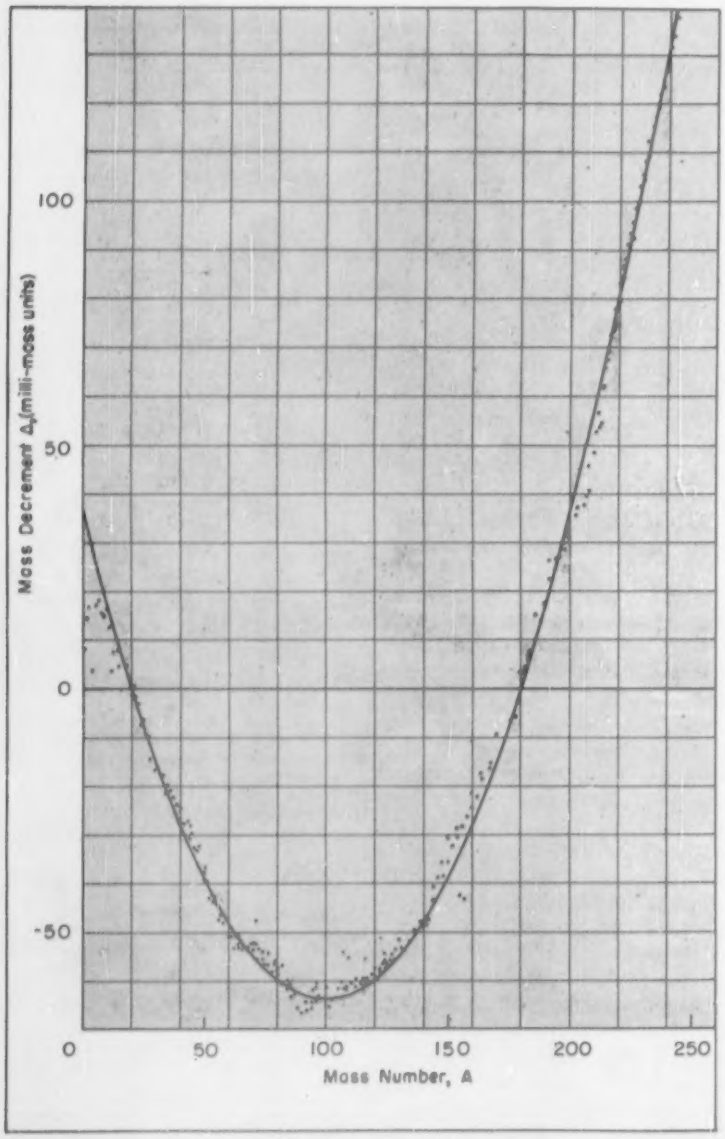


FIG. 1. Empirical mass curve matches actual nuclear masses well

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THE FIELD OF NUCLEONICS ultimately depends upon energies released or absorbed in various transformations of nuclei. While the great variety of nuclear transformations that have been induced appear unrelated and kaleidoscopic in their energy release, nevertheless there are certain general regularities. The purpose of this article is to call attention to one of the major regularities, the one provided by regularities in nuclear masses (*1–4*). It is simply revealed by a new empirical equation that accurately matches experimental nuclear masses, and a new nomogram for bombardment-reaction energies.

Empirical Mass Equation

In the course of an effort (*5*) to fit polynominals to the mass decrements, Δ, of beta-stable nuclides the simple quadratic expression

$$\Delta_m^e(A) = 0.01(A - 100)^2 - 64 \quad (1)$$

was found to provide the remarkably good representation shown in Fig. 1. (A is the mass number, Δ_m^e is in mmu, milli mass units.) Indeed this expression gave better agreement than semi-empirical expressions then available. Equation 1 is limited in its utility to mass numbers above 10 since the masses of nuclides having $A < 10$ do not conform to this or to any other simple function. The principle purpose of this article is to consider the application of Eq. 1 to the prediction of reaction energies of bombardment reactions.

A typical bombardment reaction may be symbolized as

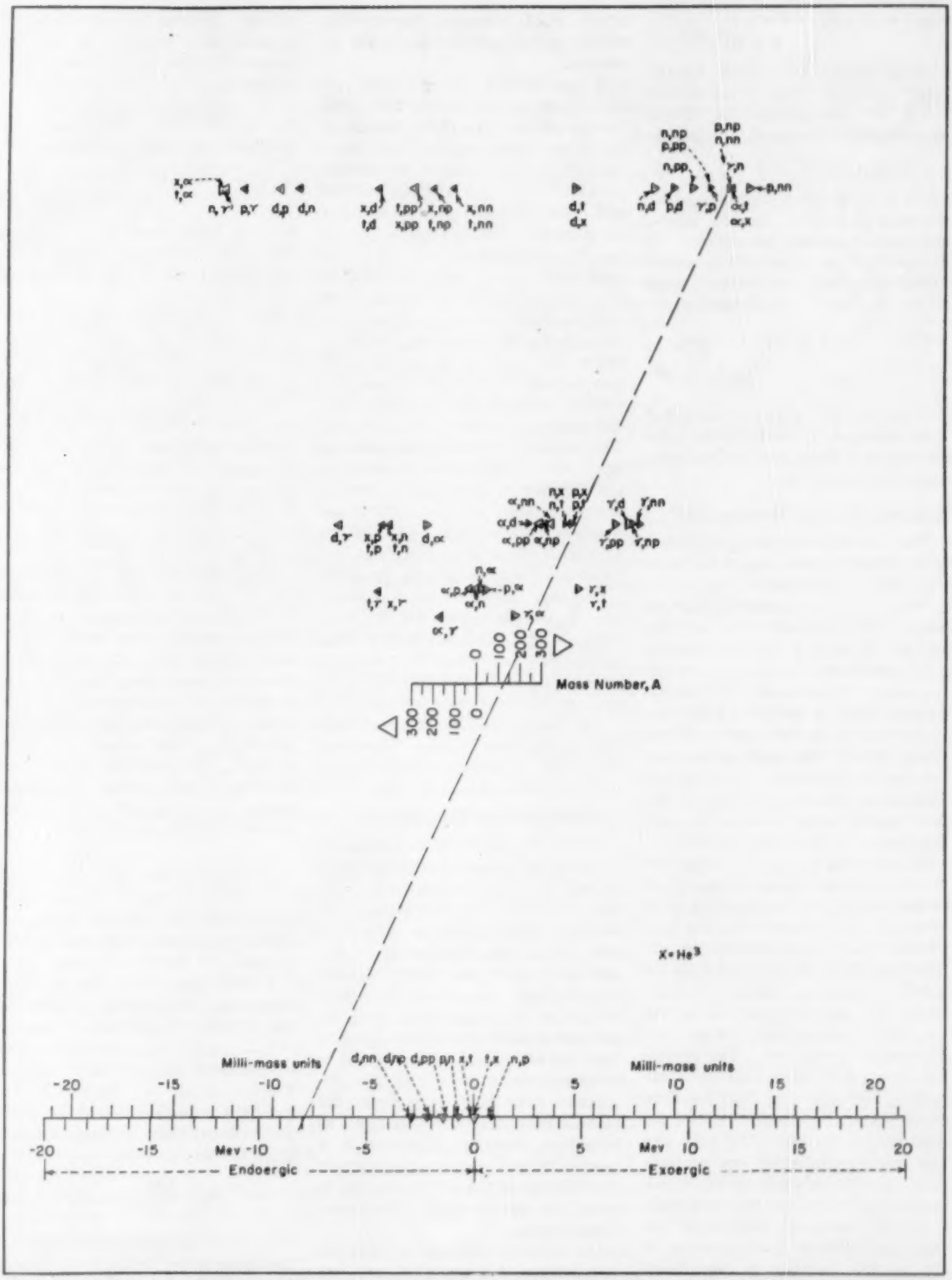

FIG. 2. Nomogram for estimating reaction energies. To use, strike a line from key point denoting incident and ejected particle to value of A on appropriate half (keyed by triangle) of horizontal mass scale. Reaction energy in Mev and mmu is indicated on horizontal scale at bottom. In the example shown, a (γ,n) reaction with Sn^{124}, a nucleus having $A = 124$, is found to be endoergic with $Q = -7.9$ Mev. The actual value is -8.5 Mev (7). This is closer than usual; residual is usually of the order of 1 Mev

$$x(a,s) + X(A,Z) \rightarrow x'(a',x') + X'(A',Z') \quad (2)$$

where x is the incident nuclide, X is the target nuclide, x' is the ejected nuclide and X' is the residual nuclide. The Q value of such a reaction may be written

$$Q = \delta - \delta' + \Delta - \Delta' \quad (3)$$

where δ, δ', Δ and Δ' are the mass decrements of incident, ejected, target, and residual nuclides, respectively. If we use Eq. 1 for Δ and Δ' but *experimental* values for δ and δ' we find, using the relation $A' = A + a - a'$

$$Q_m{}^e(A) = \delta - \delta' + 2(a - a') - \frac{(a-a')^2}{100} - \frac{2(a-a')}{100} A \quad (4)$$

The fact that $Q_m{}^e$, is a linear function of A for each type of reaction is the major advantage of Eq. 1 over various semi-empirical expressions.

Reaction-Energy Nomogram

The expression for energy released in a nuclear reaction, Eq. 4, has been embodied in a nomogram, Fig. 2. All of the usual types of bombardment reactions are included. To use this nomogram, strike a line from the key point denoting the incident and ejected particle to the value of A on the appropriate scale in the center half of the horizontal. The approximate reaction energy in Mev and mmu is then indicated on the horizontal scale at bottom. (Reactions indicated directly on the bottom scale cause no change in A and hence have constant empirical Q's.)

By sweeping the central point over the entire range of mass values of the target nuclide, we may obtain a quick survey of all Q values for a given type of reaction. Some noteworthy observations that we may make are the marked exoergic nature of (d,γ), (d,n), (d,p), and (d,α) reactions, as well as the corresponding triton- and He^3-induced reactions. The reverse reactions are of course markedly endoergic. The (p,α) and (n,α) reactions also tend to be exoergic, except for light target nuclides. We note also that reactions in which two neutrons or two protons or a neutron and a proton are ejected are generally endoergic.

The Q values of reactions of the (γ,x) type give the binding energy of the ejected particle in the initial nuclide if we reverse the sign, i.e.

$$Q[X(\gamma,x)X'] = M - m' - M' = -B_x(X) \quad (5)$$

where $B_x(X)$ denotes the binding energy of the x particle in the X nucleus.

If we use the nomogram for all (γ,x) reactions we observe that, with the exception of the alpha particle, Q values are always negative, and hence particle binding energies are always positive. The high stability of the alpha particle accounts for the fact that alpha-particle binding energies become negative for heavy nuclides. We note that this occurs approximately at $A = 150$. Accordingly we may expect nuclides above this mass number to be unstable against alpha decay and those below this value to be stable. This may appear to contradict the experimental fact that alpha instability does not occur in nature below $A = 200$. The apparent contradiction resolves itself when consideration is given to the lifetimes of alpha decay—with a few exceptions, nuclides with mass numbers between 150 and 200 *are* capable of alpha decay, but have lifetimes that are too long to be measured.

One may readily extend the nomogram to include some of the reactions induced by projectiles heavier than helium, such as C^{12} and N^{14}. For this purpose use Eq. 4 to locate the index point for the reaction of interest.

The fission reaction does not lend itself to treatment by Eq. 4. However, Eq. 1 can be applied directly to the study of fission phenomena (*6*).

Corrections and Limitations

The Q values given in the nomogram are based upon mass decrements given by Eq. 1. Actual masses depart from this expression. Furthermore, since reaction energies involve differences like $\Delta - \Delta'$, the irregularities of the mass surface are accentuated in reaction energies. Accordingly one must expect to find appreciable local departures from the predictions obtained from the nomogram. It is difficult to anticipate the magnitude of these departures since they have about the same degree of erratic variability as beta-decay energies. However, it is possible in most instances to anticipate the direction of the departures, and in some instances to estimate the corrections roughly.

Let us call the difference between the actual mass decrement, Δ, and the empirical mass decrement, $\Delta_m{}^e(A)$, the mass-decrement residual, R

$$R \equiv \Delta - \Delta_m{}^e(A) \quad (6)$$

and the difference between the actual Q value of a reaction, Q, and the empirical Q value, $[Q_m{}^e(A)]$ the residual Q value, Q_R

$$Q_R \equiv Q - Q_m{}^e(A) \quad (7)$$

It follows from Eqs. 1 and 3 that

$$Q_R = [\Delta - \Delta_m{}^e(A)] - [\Delta' - \Delta_m{}^e(A')] = R - R' \quad (8)$$

Since in beta decay $A = A'$, these residual Q values have precisely the same form as the actual Q values for beta decay.

Rules concerning the sign of Q_R can be formulated most simply by using Eq. 8 in conjunction with rules for R. Accordingly, we must formulate the conditions under which the mass defects tend to depart from those predicted on the basis of Eq. 1. These departures are negative for nuclides that are anomalously stable and positive for nuclides that are anomalously unstable (relative to the empirical values given by Eq. 1).

It is well known that nuclei with N odd and Z odd tend to be more unstable than odd-even or even-odd nuclides. They in turn are more unstable than nuclei of the even-even type. These facts have been related to the pairing tendencies of neutrons and protons. Letting n denote the degree of pairing instability of the target ($n = 2$ for odd-odd, 1 for even-odd or odd-even, and 0 for even-even) and n' denote the degree of pairing instability of the product, then (in Mev or mmu)

$$Q_{R_p} = (n - n') \frac{10}{\sqrt{A}} \quad (9)$$

is an approximate estimate of the correction associated with the pairing property.

Another correction, the parabolic correction, relates to the proximity of the initial and target nuclei to the line of beta stability. Such a line has been incorporated on the 1952 General Electric Chart of Nuclides.* The parabolic or quadratic correction to the mass decrements is approximately given (in Mev or mmu) by

$$R_q = \frac{100}{A} (Z - Z_m)^2 \quad (10)$$

where Z_m is the interpolated Z value at the intersection between the line of beta stability and the line of isobars.

* The chart can be obtained free by writing to Department 2-119, General Electric Co., Schenectady, New York.

A Review of Basic Principles

Underlying the discussion of nuclear masses and reaction energies are certain basic principles. They concern the equivalence of mass and energy, the definition of Q, the energy released in a nuclear reaction, and how it is determined by the masses in the reaction equation. This directs our attention to nuclear masses, mass decrements, and empirical formulas for them.

1. *The equivalence of mass and energy, and their relation via the square of the velocity of light is usually expressed as*

$$E = Mc^2 \qquad (12)$$

In applications of Eq. 12 one may avoid the explicit introduction of the factor c^2 by expressing energies in terms of the unit used for mass (such as mass unit or milli mass unit) or expressing masses in the energy unit (such as Mev). One milli mass unit equals 0.931 Mev.

2. *The reaction energy, Q, represents the total mass difference between the initial, i, and final, f, nuclides involved, i.e.*

$$Q = \sum_i M_i - \sum_f M_f \qquad (13)$$

Neutral atomic masses can be used throughout since the total number of electrons missing from the initial particles is equal to the total number of electrons missing from the products.

3. *The mass of any nuclide, measured on a scale in which one atom of $O^{16} = 16.000000$ mu, is approximately an integral number. This integral number (A) is called the mass number and is equal to the number of neutrons (N) plus the number of protons (Z) in the nucleus of that atom. The small deviation of the actual mass of a nuclide from its A,*

$$\Delta \equiv M - A \qquad (14)$$

is called the mass decrement or mass defect.

4. *In any nuclear reaction, charge is conserved, and the total number of nucleons, neutrons and protons, remains unaltered*

$$\sum_i Z_i = \sum_f Z_f, \qquad \sum_i A_i = \sum_f A_f \qquad (15a), (15b)$$

In view of Eqs. 13, 14, and 15b, the Q of any reaction is

$$Q = \sum_i \Delta_i - \sum_f \Delta_f \qquad (16)$$

5. *If the mass decrements of all but the very lightest nuclides are plotted in three dimensions against N, and Z, the assembly of experimental points lie fairly close to a smooth average surface, the so-called mass surface. Thus it is profitable to regard the mass decrement as a function of N and Z, i.e.*

$$\Delta = \Delta\,(N,Z) \qquad (17)$$

Unlike ordinary functions, $\Delta(N,Z)$ is defined only for integral values of N and Z and is somewhat irregular.

6. *The available mass data indicates that mass decrements depend mainly on A*

$$\Delta(N,Z) \approx \Delta_m(A) \qquad (18)$$

where, (see remarks after Eq. 10) the subscript m denotes minimum. The experimental data also reveal that nuclear masses depend to a smaller extent upon a host of other variables, such as the oddness or evenness of the neutron and proton numbers, the deviation of N and Z from the so-called magic numbers, the deviation of the neutron excess, $N - Z$, for a given A from a most favorable neutron excess for that value of A, as well as other less-well-understood variables.

A number of theories (1–4) have been put forth to account for nuclear masses. The mass surface defined in this article is based on a purely empirical match to the observed nuclear masses.

This point represents the minimum of the mass decrement parabola. If, as is most often the case, the target lies closer to this line than the product, the parabolic correction to Q_R is negative. An estimate of the magnitude of the quadratic Q-value correction may be obtained using (in Mev or mmu)

$$Q_{R_q} = \frac{100}{A}\,(\varphi^2 - (\varphi')^2) \qquad (11)$$

where $\varphi = Z - Z_m$ and $\varphi' = Z' - Z_m'$.

A third correction might be identified with the unusual stability (according to shell-structure theory) of nuclides that have the magic N or Z numbers 2, 8, 20, 28, 50, 82 and 126. Accordingly, if the target nuclide's N and Z lie closer to these magic numbers than the product's, then there will be a negative shell-structure contribution to the Q values. The correction depends sensitively upon the proximity of N and Z to magic numbers so that no simple rule can be given for this correction (*10*).

Other corrections might be formulated to embody other fine characteristics of the mass surface that have been noted (*8–10*). However, with our present knowledge of nuclear masses the point of diminishing returns sets in very rapidly in the application of fine corrections to mass and Q-value predictions.

The simple empirical expression for mass decrements, Eq. 1, and the derived expression for reaction energies, Eq. 4, reveal the general trends of a large quantity of experimental information. They also provide a basis for predicting unknown nuclear masses and energies. They have been used as references to facilitate a detailed study of the actual mass surface and various theoretical mass surfaces (*10–12*). It is hoped that they may serve useful purposes to those concerned with applications of nuclear energy.

* * *

The writer wishes to thank the Research Council of Florida State University for its support of this work and Mr. Richard Gentry for his careful construction of the nomogram.

BIBLIOGRAPHY

1. C. F. von Weizsäcker, *Z. Physik* **96**, 431 (1935)
2. H. A. Bethe, R. F. Bacher, *Revs. Mod. Phys.* **8**, 165 (1936)
3. E. P. Wigner, *Phys. Rev.* **51**, 106 (1937)
4. E. Feenberg, *Revs. Mod. Phys.* **19**, 239 (1947)
5. A. E. S. Green, *Phys. Rev.* **85**, 1248 (1951); **86**, 654 (1952)
6. A. E. S. Green, "Nuclear Physics" (McGraw Hill Book Co., Inc., New York, 1955)
7. A. O. Hanson, R. B. Duffield, V. D. Knight, B. C. Diven, H. Palevsky, *Phys. Rev.* **76**, 578L (1949)
8. C. D. Coryell, in "Annual Review of Nuclear Science," Volume 2, p. 305 (Annual Reviews, Inc., Stanford, California, 1952)
9. H. E. Suess, J. H. D. Jensen, *Arkiv. Fysik*, **3**, 577 (1951)
10. A. E. S. Green, D. F. Edwards, *Phys. Rev.* **91**, 46 (1953)
11. A. E. S. Green, N. A. Engler, *Phys. Rev.* **91**, 40 (1953)
12. A. E. S. Green, *Phys. Rev.* **95**, 1006 (1954)

Spurious counts due to humid flow gas can be eliminated with proper choice of gas and discriminator level. Gases of lower ionization potential than water—e.g., ethane—provide useful plateaus at 79% relative humidity

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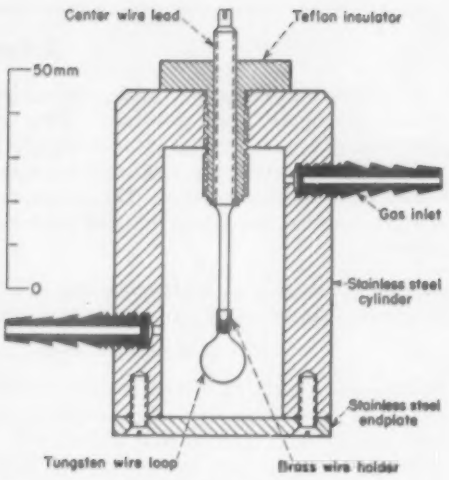

FIG. 1. High-humidity flow counter

Proportional Flow Counter with High-Humidity Gas

A PROPORTIONAL FLOW COUNTER, designed to operate with high-humidity gas, promises to be useful for measuring adsorbed substances on water surfaces and T_2O from oxidation of tritiated organic compounds.

G-M and proportional counters have presented certain difficulties. In measuring the concentration of tritium-labeled soaps in water surfaces, the counter window and the gas between the water surface and window absorb a large part of the soft beta radiation. The distance between the sensitive volume of the counter and the water surface is also critical. A 0.01-mm variation of the latter is estimated to give a variation in the observed activity of about 1% when the gas space between surface and window is filled with moist air. A windowless flow counter with its sensitive volume extending to the water surface would eliminate these difficulties. It has to operate, however, at a high humidity since the evaporation from the water surface must necessarily be kept as low as possible. A description of such a counter has not been found in the literature.

There are at least three ways in which spurious counts can be produced by a water molecule, making it undesirable in a counting gas mixture (*1*):

1. Its tendency to capture the free electrons formed by the ionizing particle, producing H_2O^-. When such an ion arrives at the high-field region close to the wire, the electron is stripped off and a spurious count may result. In a proportional counter, the capture of primary electrons also results in reduced amplitude of the genuine pulses.

2. H_2O^+ ions formed (a) in the avalanche or (b) through charge exchange with the counting gas may form negative ions (through dissociation or electron capture) when reaching the cathode, which behave as in 1.

3. H_2O^+ ions, when reaching the cathode, may produce secondary electrons, which discharge the counter.

Spurious Pulse Reduction

If the electric field strength in the counter is sufficiently high, then 1 may not be important. When spurious counts are produced in this way, they are spread out in time and appear in a proportional counter as separate pulses of lower amplitude than the genuine ones. It is thus possible to eliminate them by choosing a suitable discriminator level without losing too many genuine pulses. This is not possible in a G-M counter where all pulses appear with equal size.

The pulses from 2 and 3 may, however, be sufficiently contemporary to build up a single pulse of high amplitude against which it is more difficult to discriminate. Now the mechanisms 2 and 3 could be completely eliminated by using a suitable counting gas of lower ionization potential than H_2O. In this case a charge transfer goes from H_2O^+ to the counting gas molecules, and, if efficient, this would reduce the number of H_2O^+ reaching the cathode to such an extent that the resulting secondary pulse becomes lower in amplitude than the discriminator level.

Unsuccessful attempts to obtain a windowless proportional flow counter with a good plateau when water vapor

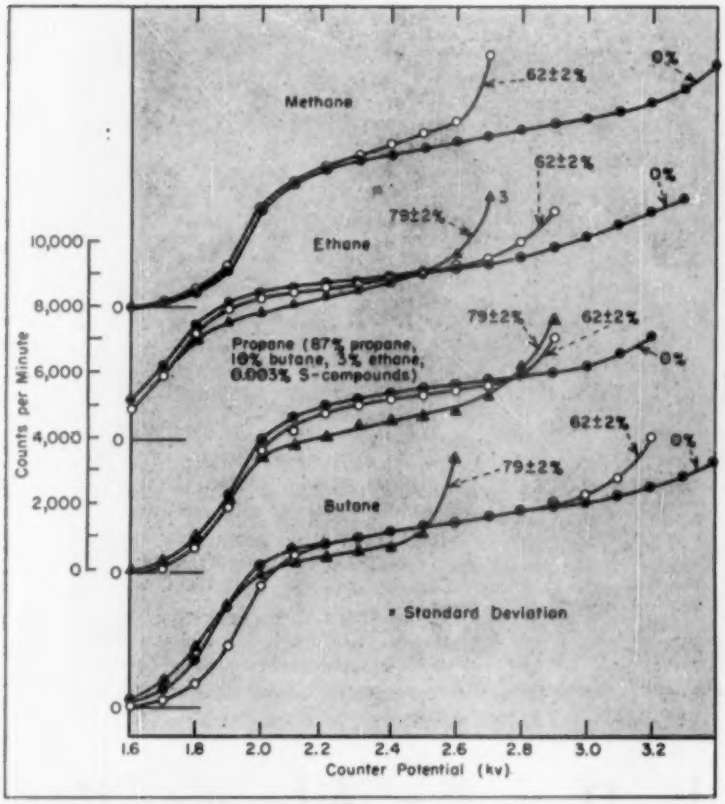

FIG. 2. Plateaus obtained with gases at different humidities

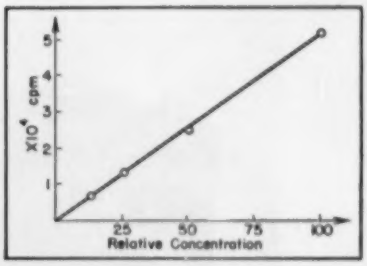

FIG. 3. Proportionality of source strength vs $Ca^{45}Cl_2$ at 79% humidity

Gas Ionization Potentials

Gas	*Ionisation potential (ev)**
Water	12.56
Helium	24.46
Methane	13.1
Ethane	11.6
Ethylene	10.80
Acetylene	11.2
Propane	11.3
n-butane	10.34

* Values taken from Landolt-Börnstein.

was present were made with two gases: methane and helium + 4% *n*-butane. This may be explained by the fact that methane and helium have higher ionization potentials than water (see table) and that the small amount of *n*-butane in the latter case could not change the properties.

Successful Attempts

Subsequent experiments with moist ethane, propane, and butane as flow gases gave very encouraging results. These gases all have lower ionization potentials than water, and mechanisms **2** and **3** would be reduced as described previously.

The counter used is shown in Fig. 1. The radioactive source was in all cases 20-mc lead-shielded Co^{60} 1 meter from the counter. The counting equipment was composed of EKCO H. F. head amplifier type 1008, pulse amplifier type 1008, scaler type 1009, and Labgear E.H.T. supply unit type D 4019/p. Integration and differentiation time constants were 0.6 μsec, bias, 5 volts, and gain, 16×10^3. The flow gases had to pass a washbottle with a concentrated salt solution thermostated at 25° C to get the desired humidity. The humidity of the gas was measured with a resistance hygrometer,* and the gas flow was in all cases about 5–15 ml/min. The tube was held at 27° C.

The plateaus obtained are shown in Fig. 2. At 62% relative humidity, the curves for ethane, propane and butane almost coincide with the curves for the dry gases, although the plateaus are somewhat shorter. At the same humidity methane gives a much inferior plateau and helium + 4% butane gives no plateau at all.

At the higher humidity of 79%, the three gases still give useful plateaus. The presence of water reduces the counting rate, probably through capture of primary electrons by water molecules. As this effect should be independent of source strength, it should be of little importance in relative measurements. To test this proportionality to source strength, measurements were made with propane on water solutions of tracer amounts of $Ca^{45}Cl_2$ in four different concentrations. Sodium hexametaphosphate (5 gm/l) was added to the solutions to prevent adsorption of calcium ions on surface-active impurities (*2*). In Fig. 3 the proportionality appears satisfactory.

Ethylene and acetylene, both having lower ionization potentials than water, were also tested as counting gases. With ethylene, no useful plateau was obtained even in dry condition, whereas with moist acetylene a useful plateau could be obtained. The sensitivity to water vapor seems however to be greater than for the saturated hydrocarbons. This shows that phenomena other than those previously mentioned may be of importance in this connection but does not contradict the working hypothesis that the gas should have an ionization potential lower than that of water.

* Developed by T. Westermark of this institute.

BIBLIOGRAPHY

1. D. H. Wilkinson, "Ionization chambers and counters" (Cambridge University Press, New York, 1950)
2. G. Aniansson, *J. Phys. and Coll. Chem.* **55**, 1286 (1951)

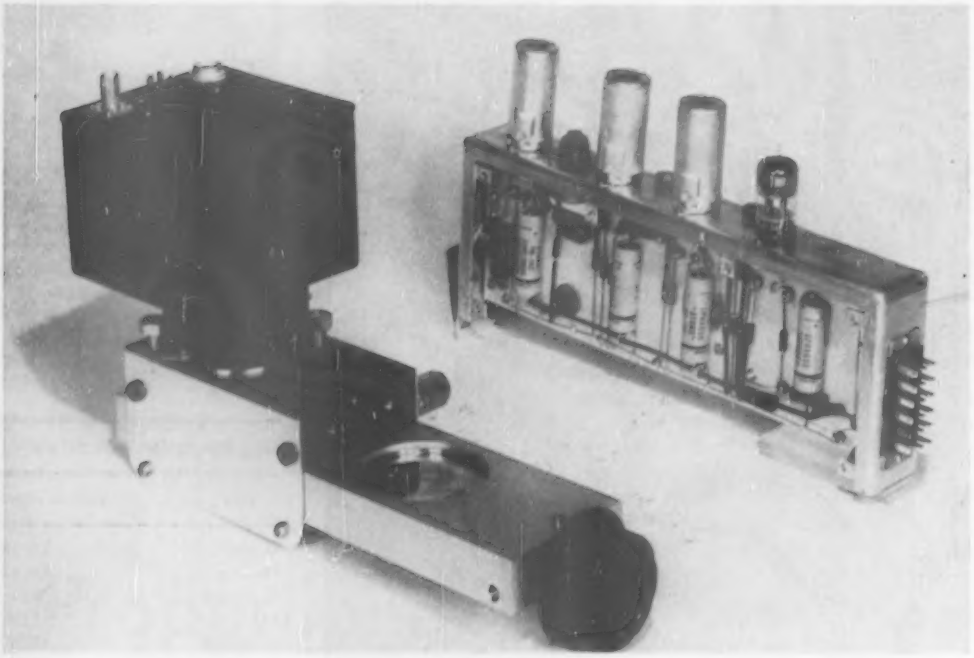

FIG. 1. Windowless counter, preamplifier, and main amplifier

Very Wide-Range Absorption

A windowless proportional counter and wide-range amplifier are used with absorbers ranging in thickness from below 10 $\mu g/cm^2$ to above 75 mg/cm^2. The combination permits identification of particles from 10-kev betas to 5-Mev alphas. Techniques for constructing very thin absorbers are given

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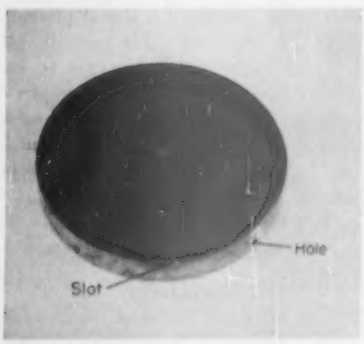

FIG. 2. Manipulator for lifting thin Formvar films with wire loop

A SIMPLE SYSTEM for identifying unknown emitters in a mixture of alpha, soft-beta, hard-beta, and photon emitters of small total activity has been developed. Three essential parts of the system are: (1) a windowless proportional absorption chamber so constructed as to hold different absorbers in proper geometrical relation to the sample; (2) absorbers suitable for use in the chamber; and (3) an amplifier capable of handling the wide range of amplitude and width of pulses from the chamber. These components are shown in Fig. 1. The system is compact, has low power requirements, is relatively inexpensive (compared with pulse-height-analysis systems), and can be operated by reasonably inexperienced personnel.

* PRESENT ADDRESS: Special Devices Group, Electronics Division, Westinghouse Electric Co., Baltimore, Maryland.

Windowless Chamber

The proportional absorption chamber (*1*) was fabricated from a standard Nuclear Measurements Corporation slide mechanism by replacing the piston with one provided with a recess for

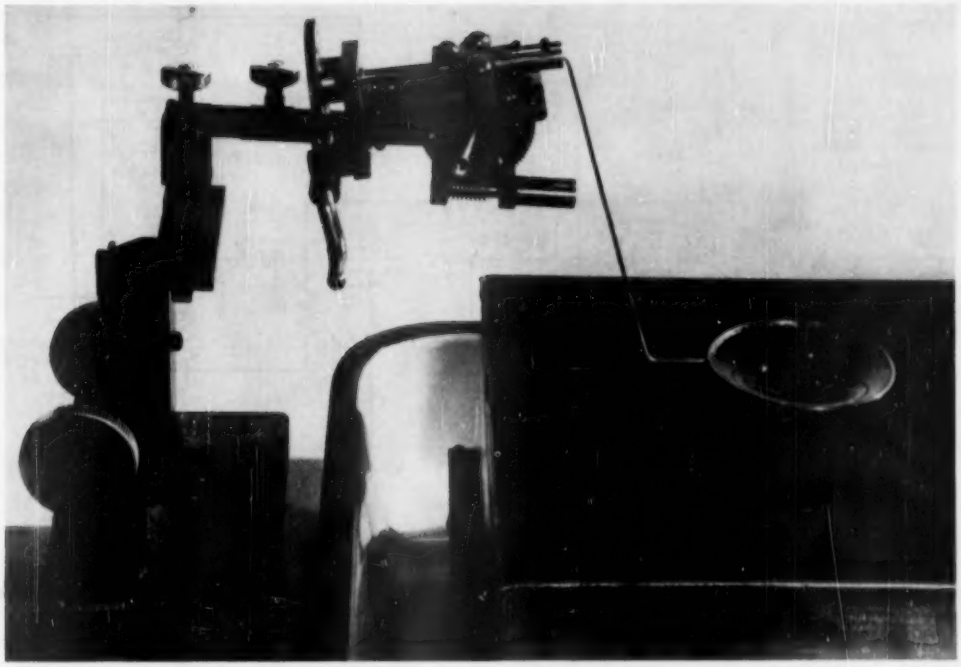

FIG. 3. Plastic film mounted on ring. Slots and holes permit circulation of gas

Counting System

absorbers. Absorbers can be positioned between the proportional chamber above and a sample of radioactive material placed below. By using absorbers fabricated from various weights of materials, energies of radiations can be determined.

The piston is provided with passages by means of which the counting gas can be introduced beneath the absorber. Passages in the absorber mount conduct the gas over the top of the absorber and permit it to escape through the proportional chamber, carrying with it air introduced during the changing of absorbers or samples.

Thin Absorbers

Absorbers (*2*) are of two types: (a) those weighing less than 35 mg/cm², which are prepared as foils and mounted on brass mounting rings; and (b) those weighing more than 75 mg/cm², which are machined as a single unit. The former (thinner ones) will be discussed here; the latter (thicker ones), in the next section.

1. Plastic-film absorbers, 10–100 μg/cm². These are made by placing a drop of a solution of Formvar-E in ethylene bromide on cold (14° C) tap water. After the solution has spread and the solvent evaporated, the film can be lifted with a wire loop. A manipulator is useful in handling the films, particularly the very fragile thin ones. Figure 2 shows a manipulator lifting a loop on which is a film about to separate from the water surface. A few drops of wetting agent reduce surface tension of the water, permitting the film to separate cleanly. The film is rinsed by holding it in a vertical position and carefully pouring distilled water over it; then it is permitted to dry.

The plastic films are made conducting by coating the surface with aluminum or silver in a small vacuum evaporator. Careful manipulation, such as the use of a heat shield and the avoidance of rapid temperature changes, prevents rupturing the films.

A solution containing 2% by weight of plastic gave films in the range of approximately 4 μg/cm². These films were coated by evaporation of aluminum to a total weight range of approximately 10–20 μg/cm². A solution containing 4% by weight of plastic gave 15-μg/cm² films; these films were coated with silver by evaporation to a total weight range of approximately 20–100 μg/cm².

The completed films were transferred to a ring whose weight had been deter-

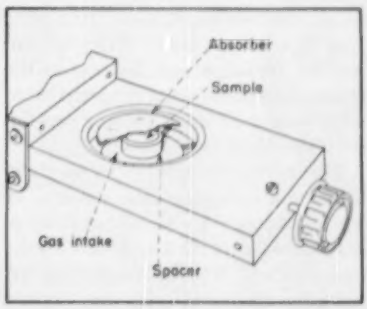

FIG. 4. Cutaway view shows detail in absorption chamber

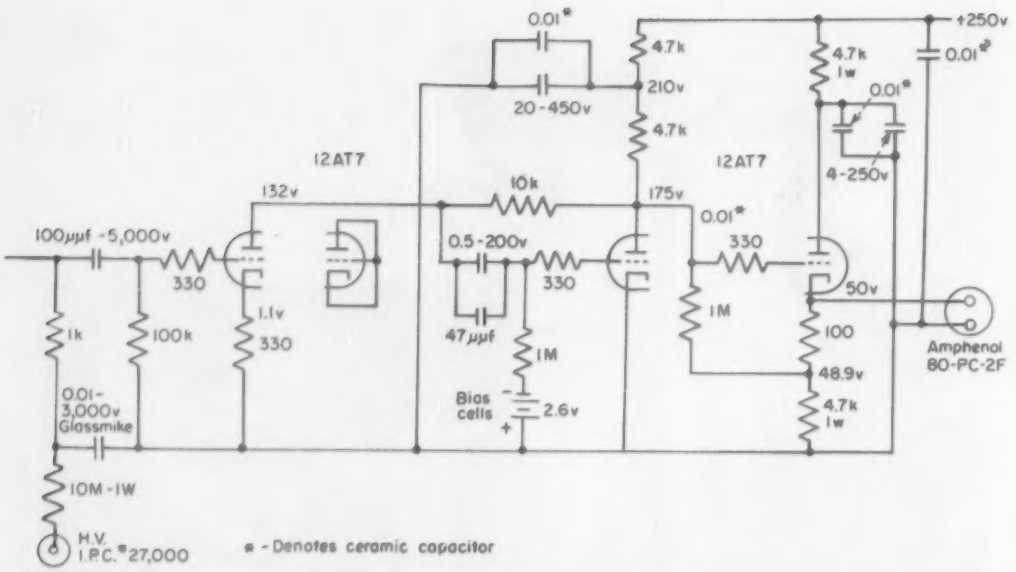

FIG. 5. Preamplifier. All resistors are ½ watt unless otherwise noted. Center tap of filament transformer must be grounded. Common ground of the preamplifier is not connected to the chassis

mined in advance. Weighing the assembly and subtracting gave the weight of the film. This intermediate weighing ring was used, rather than the final absorber mounting ring, to increase the accuracy of the determination and stay within the load limit of the microbalance used.

2. Aluminum electroscope-foil absorbers, 150–900 μg/cm². Supposedly uniform, electroscope foils actually vary in weight from 120 to 230 μg/cm². By lamination of weight-selected sheets, any desired absorber weight can be obtained. Four laminations, however, were about all that could be assembled without undue difficulty.

Electroscope foil is very difficult to handle, but it must be taut on the absorber ring to eliminate wrinkles. If the absorber is fabricated from laminated foil, the sheet must be taut to eliminate bubbles. The foil was expanded by heating it on a Pyrex plate placed on a hot plate. When the foil was hot, its edges were fastened to the Pyrex plate with rubber cement diluted with benzene. Upon cooling, the foil contracted and became taut.

The foil was transferred by carefully lowering a mounting ring, the edge of which was coated with rubber cement, onto the foil. This was done with the manipulator. The foil extending beyond the edge of the ring was cut and the ring, with foil attached, was removed. Laminated sheets were made successfully by this same method. A few drops of amyl acetate placed on the surface of each layer caused each succeeding sheet of foil to adhere.

Sometimes pinholes in a single-foil absorber are objectionable, in which case a single thin plastic film can be laminated over the mounted foil. The interfaces can be joined by wetting the foil side with a few drops of amyl acetate, after which aluminum can be evaporated onto the film.

3. Commercial-aluminum-foil absorbers, 1.6–35 mg/cm². These are fabricated easily by cutting the foil and attaching it to the mounting rings.

A complete plastic-film absorber is illustrated in Fig. 3. The slots at the top and the oblique holes through the sides of the ring permitted counting gas to circulate around the absorber. The holes were positioned at an angle to prevent the direct escape of radiation into the sensitive volume of the chamber.

When an absorption measurement was made, the sample was placed on a spacer that rests on the bottom of the absorption chamber. The absorber ring was placed on a ledge that extends around the inside of the chamber. The top of the spacer was 0.075 in. below the film, thereby keeping absorption by the counting gas (usually 90% argon, 10% methane) at a minimum and also maintaining optimum geometry conditions. Figure 4 is a top view of the absorption chamber with a spacer, a sample, and an absorber in place.

Thick Absorbers

When absorber thickness exceeds 75 mg/cm² (0.01 in.) it is convenient to machine both absorber and mounting ring as a single unit from aluminum bar stock. As absorber thickness is increased, the ring must be thinned an equal amount to keep the total thickness constant. This is necessary because the electrostatic field pattern is altered if the distance from center wire of the chamber to top of the absorber varies. The spacers used with one-piece absorbers must also be adjusted in thickness to maintain a constant sample-top–absorber-bottom distance.

Amplifier

The amplifier for this counting system has these characteristics (*3, 4*):

1. High gain so that low-ionization events can be recorded.

2. Wide dynamic range; a given sample may have components ranging in energy from a few kev to a few Mev.

3. Short-duration pulses to minimize resolution loss.

4. Nonoverloading so that events will not be lost during recovery.

Linearity was not necessary since we were interested only in counting and not in analyzing. It was desirable for the amplifier to be as simple as possible consistent with performance. The cir-

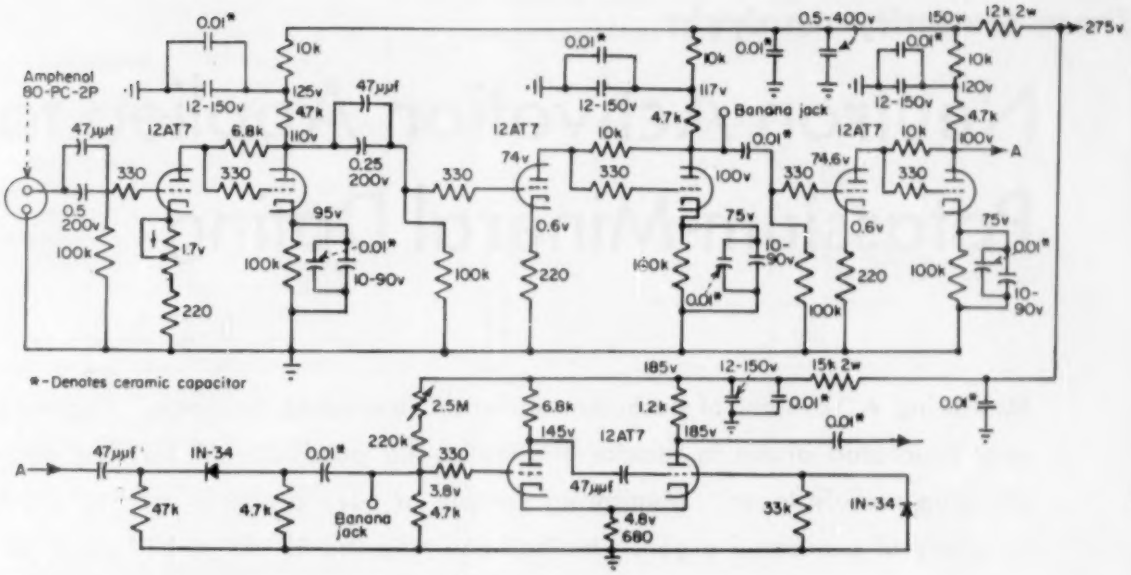

FIG. 6. Main amplifier. All resistors are ½ watt unless otherwise noted

cuits adopted are shown in Figs. 5 and 6.

Sensitivity of the completed amplifier has not been evaluated in terms of the energy corresponding to the minimum detectable pulse. However, the maximum energy of lead recoil atoms has been measured accurately by absorption studies, and absorption studies of very weak pulses (from Ra D) in the presence of very strong pulses (from Ra F) have been made (*5*).

Maximum signal-to-noise ratio was obtained by mounting a single-stage preamplifier at the chamber and feeding the preamplifier output through a cathode follower to the input of a three-stage main amplifier. Long-time-constant *RC* networks, consistent with the gain of the succeeding stages, insured wide dynamic range (*6*). The amplifier sensitivity for the minimum usable signal-to-noise ratio was approximately 50 microvolts, and the dynamic range was in excess of 6,000.

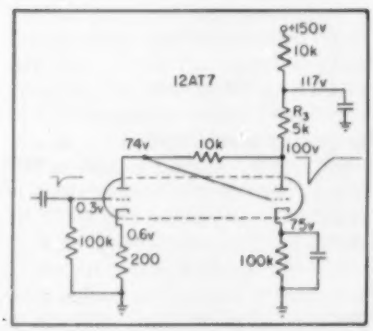

FIG. 7. Compressor used to limit pulse heights to avoid overloading amplifier

Short-duration pulses (*7*) were achieved by using a 1,000-ohm chamber load resistor (this also aided pulse limiting) and by maintaining a reasonable over-all frequency response. The system resolving time for alpha-particle pulses on the alpha plateau was approximately 4 μsec (with a 4-μsec scaler) and increased to 12 μsec on the alpha-plus-beta plateau. Over-all rise time of the amplifier was 0.25 μsec, and frequency response was down 3db at 500 cycles and 2 megacycles.

Nonoverloading was obtained by using a negative-input, direct-coupled triode pair that automatically decreased the amplifier gain with increased signal input. The basic circuit of this direct-coupled pair has been used at the M. I. T. Radiation Laboratory (*8*). Circuit simplicity permitted economic construction.

The circuit, shown in Fig. 7, limits in an exponential manner without blocking or appreciable undershoot. A negative signal at the input grid decreases the current in the first triode, applying a positive pulse to the second grid. This positive pulse increased the current through the second section of the dual triode, driving its plate voltage toward zero and thereby causing a negative pulse to appear at the output plate. A large percentage of this pulse (70–95%) was fed back to the second grid. This feedback limits the grid swing of the second section to approximately 0.5–1 volt for a 10-volt input signal. Since the output of the input section is limited to about 10 volts, the negative output pulse is limited to approximately 10 volts. The common load resistor R_3 also contributes to limiting because one-third of the voltage at the plate of section one is opposed to the negative output pulse of section two.

Power supply requirements include a constant-voltage, center-tapped supply for the filaments; a 250-volt d-c, 35-ma regulated supply; and a 0–2,500-volt d-c ionization-chamber supply

* * *

Mound Laboratory, where this research was conducted, is operated by Monsanto Chemical Company for the U. S. Atomic Energy Commission under contract AT-33-1-GEN-53.

BIBLIOGRAPHY

1. L. B. Gnagey. A windowless proportional chamber for absorption measurements, MLM-857 (1953)
2. J. S. Stanton, J. W. Heyd. The preparation of plastic and metallic absorbers, MLM-858 (1953)
3. W. H. Baker. Counting systems for pulses of wide dynamic range, MLM-618 (1951)
4. W. H. Baker. A nonlinear pulse amplifier of wide dynamic range, MLM-851 (1953)
5. M. L. Curtis, J. W. Heyd. Windowless absorption counter for routine energy measurements of soft radiations, MLM-842, p. 6 (1953)
6. H. J. Lipkin in "Vacuum Tube Amplifiers," G. E. Valley, Jr., and Henry Wallman, ed., Radiation Laboratory Series, Vol. 18, p. 114 (McGraw-Hill Book Co., Inc., New York, 1948)
7. W. B. Lewis. "Electrical Counting," p. 116 (Macmillan Co., New York, 1942)
8. Page 157 of reference 6

Trace-Quantity Analysis:

Neutron Activation Applied to Potassium-Mineral Dating

Measuring A^{40} content of potassium minerals determines their age. Exposing only separated argon in reactor eliminates the possibility of forming complicating radioisotopes. Monitoring sample of pure argon is used to check on purity of separated argon. Method can measure 30–40 $\times$ 10^{-9} gm of A^{40}

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AGE OF POTASSIUM-CONTAINING MINERALS can be determined by measuring the amount of radiogenic argon, A^{40}, contained within a known mass of potassium, provided that the argon has not escaped in appreciable amount, and provided that the branching ratio and half-life of K^{40} are known.

Neutron-activation analysis is the means used in this study for determining A^{40}. Only the A is exposed in a reactor, to avoid the formation of complicating radioisotopes from constituents of the solid mineral. Effectiveness of the separation method in yielding uncontaminated A is checked by following sample decay and by comparing its radiation to that of a calibration sample of pure A. The calibration sample also is used to determine the constants involved in reactor irradiation and in the counting instruments.

On account of the relatively slow decay and the low abundance of K^{40} in potassium, the amount of A^{40} produced in minerals about 10^8 yr old is of the order of 1 ppm by weight of total potassium. This represents a fairly difficult problem in gas analysis, but such analysis has been satisfactorily performed in several instances (*1–4*). At the lower argon concentrations found in minerals 10^6 yr or less in age the difficulties are greatly increased. It is in this region that a neutron-activation method (*5*) appears to be very useful.

Neutron Activation

In application of this technique the chief difficulties are avoided by pretreating the mineral to yield A^{40} as a gas. Irradiating this gas leads to converting some A^{40} to A^{41} by the (n,γ) reaction. Because the decay period of A^{41} (a 1.5-Mev beta emitter) is 1.8 hr the irradiation must last several hours, say 4–10, for nearly maximum radioactivity. If effective neutron flux is φ and bombardment time is long compared with the half-life, the activity produced is $\sigma\varphi n$, where σ is the integrated cross section and n is the number of A^{40} atoms irradiated. By measuring the activity subsequent to activation, and knowing $\sigma\varphi$, the value of n can be obtained. In practice φ and σ are not considered separately. The product $\sigma\varphi$ is, in fact, determined experimentally by irradiating a known amount of pure argon in a quartz container placed in the reactor near the sample of radiogenic argon. Comparison with this monitoring gas allows us to estimate closely the amount of radiogenic A^{40} that had been released from the mineral.

Knowledge of this value yields us specimen age. For specimens of age t, very much less than the half-life of K^{40} we can substitute in the general decay equation, $dN = -\lambda N\, dT$, the values n for dN and t for dT, giving us $n = -\lambda_k N t$. Here n (amount of A^{40}) λ_k (partial decay constant for K-capture), and N, (original number of K^{40} atoms) are known; therefore t can be calculated. In practice only a definite known fraction of the A^{40} is irradiated.

The gas liberated from the mineral is exposed to the neutrons rather than the mineral itself, since otherwise a number of complicating radioactive elements are created. By this pro-

cedure impurities are avoided to a large extent. Two sources of error must be guarded against. They are: atmospheric contamination of the sample, and solids entering the sample vessel.

If atmospheric argon is present as a contaminant, an erroneously high amount of A^{41} will be produced. Atmospheric argon can be traced by searching for evidence of A^{37} in the irradiated material. This isotope would be formed by (n,γ) reaction with A^{36} and is easily identified in a proportional counter because it emits only homogeneous K-capture radiation. In addition, the 37 day half-life is a useful identifying characteristic. Unfortunately, perhaps this test is not entirely satisfactory, as A^{37} is also formed in an (n,α) reaction with Ca^{40}, which is present in potassium minerals, at least as a radiogenic element. The absence of A^{37} in the irradiated sample of gas is nevertheless conclusive proof that both calcium and atmospheric argon are absent and sufficient indication that the gas is radiogenic argon.

The (n,p) reaction with K^{41} (6.91% abundant) yielding A^{41} makes the presence of solid potassium, even in minute quantity, particularly undesirable. The most critical point in gas-sample preparation is the need to keep all solid material out of the vessel.

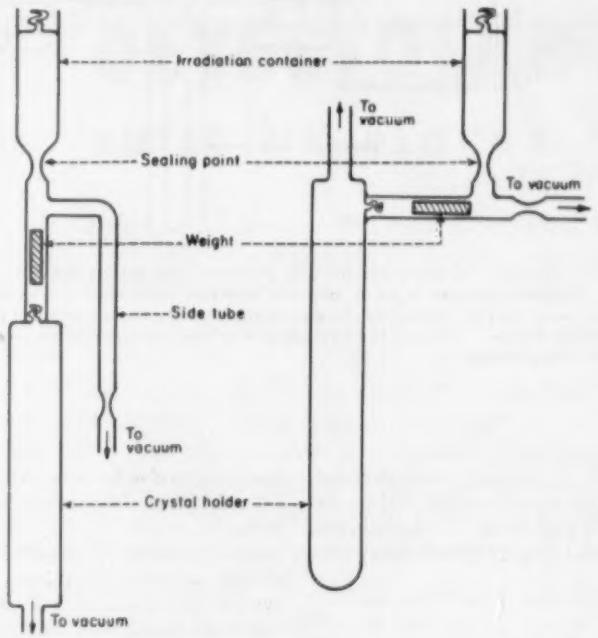
The mode of preparing test samples, explained in "Preparing Gas Samples," (right), was designed to overcome the experimental hazards of atmospheric contamination and solid carry-over. Results indicate that there were no serious difficulties in doing so.

Measurements

Samples were irradiated for 4 hr at the Atomic Energy Research Establishment at a flux of 10–12 $\times$ 10^{11} n/cm²/sec. Measurements started at Glasgow 6 hr after terminating irradiation. The delay was not altogether a hindrance, as all the possible rather short-lived activities had disappeared before observations commenced.

The quartz irradiation vessels were fairly strongly activated (equivalent to several mc). They were placed within the assembly shown in Fig. 1. This assembly was connected to the proportional counter, and to its filling system. The sample was passed into the counter, together with a mixture of argon and methane. Counter gain was such that, by reference to calibrating X-rays from a source of Ge^{71}, all beta particles

Preparing Gas Samples



QUARTZ APPARATUS for obtaining A^{40} gas from KCl by fusion (left) and by dissolving in water (right)

The mineral used in testing the method was sylvite, KCl, obtained from the Stassfurt deposits. The gas was released in two different ways, (a) by salt fusion, and (b) by dissolving in pure water. The fusion method gives less contamination.

Fusion. *Apparatus for collecting the gas when salt fusion is used is shown at the left above. It is degassed at roughly 1,000° C before use. The irradiation container is shaped to fit the cans used at Harwell. Its volume is kept as large as possible relative to that of the whole apparatus. Volumes of the various parts have to be known accurately to calculate the gas fraction actually irradiated.*

The crystal holder is filled with selected crystals and the bottom is constricted. Then the holder is pumped down to 10^{-4} mm Hg and sealed. The whole apparatus is put in a furnace and the mineral crystals melted. After gentle rocking for about an hour at fusion temperature the apparatus is allowed to cool.

Next, the irradiation container is thoroughly evacuated through the side tube and the tube sealed. At this stage the weight within the neck is used to break the thin spiral seal on the upper end of the holder. The radiogenic gas then is shared between the two vessels. Then, the side tube is used as a liquid-air trap. Gas in the irradiation container is finally sealed by heating the constricted neck.

Dissolving. *Apparatus used in liberating the argon by dissolving in water (right, above) is rather similar to that just described. The crystal holder is filled with crystals, constricted at the top, pumped out, and immersed in liquid air. Water is distilled into the holder from a large crystal of water, specially prepared from degassed water. The holder then is sealed.*

Next, the liquid air is removed and the crystals naturally dissolve in the water. The apparatus is shaken vigorously and the holder again inserted in liquid air. After evacuating the irradiation container and sealing the evacuation tube, the spiral seal is broken. The argon then distributes between the two vessels. The irradiation container is sealed. Liquid air around the crystal holder traps water vapor there.

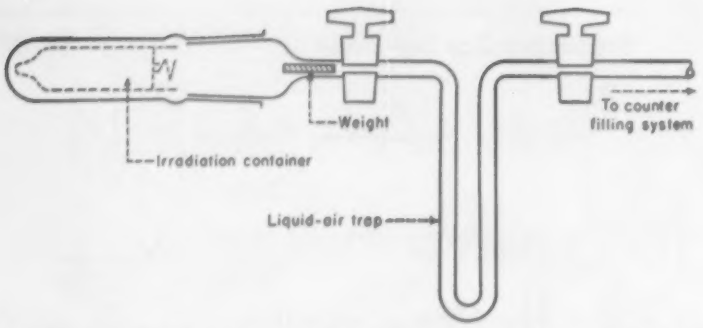


FIG. 1. Assembly for filling counter with irradiated-gas sample has a liquid air trap. Sample container is put in assembly, assembly evacuated and spiral seal broken, using weight. Stopcocks are preadjusted so that definite fraction of sample passes into U-tube. Gas is cooled by liquid air and then released into the evacuated counter-filling system

over 100 ev in energy were detected.

Activity decay was followed for between 12 and 24 hr in different runs. Decay time (Fig. 2) agreed closely with the known value for A^{41}. About 24 hr after the initial observations were completed, a search for the possible A^{37} peak at an energy of about 2.6 kev was carried out with a Hutchinson-Scarrott type of kicksorter. It was established that if the sample were prepared by the fusion method, atmospheric argon contributed <5% of the A^{40} yield. Observing the ratios of A^{37} to A^{41} for the mineral-derived argon and the pure-argon calibration sample served as a reliable method of estimating the amount of contaminating atmospheric argon in the mineral-derived gas.

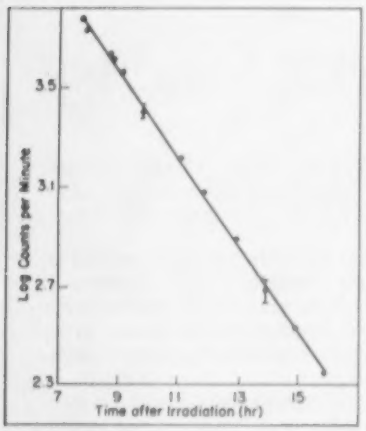


FIG. 2. Linear semi-log decay curve shows purity of A^{41} produced by (n,γ) reaction on A^{40}. The A^{40} sample was obtained from fusion of sylvite

An Alternate Method

We have concentrated here on using A^{41} produced from A^{40}. It is possible that even more reliable data could be obtained by using the (n,α) reaction on radiogenic Ca^{40}. The A^{37} produced in this process is eminently suitable for analysis even in extremely small amounts, and control samples could be used to insure procedure reliability.

Results and Discussion

Mineral age was found to be 6×10^7 yr. Branching ratio for *K*-capture was taken as 11% (two very recent measurements done in this department lie in the range 11–12%) and half-life for K^{40} decay was taken as 1.3×10^9 yr.

The method of dissolving in water appeared to give less reliable results. Some of this uncertainty could undoubtedly be ascribed to increased contamination.

It would appear that the method of dating by neutron activation is entirely practicable and relatively simple, and that estimation of ages down to about 10^4 yr could be achieved. The monitoring sample of pure argon seems to act as a very adequate safeguard against impurities. At present the main difficulty encountered is in regard to the final sealing off of the irradiation vessel. If any of the solid material can settle near the sealing point then the unavoidable heating during sealing can release this into the irradiation vessel.

We are inclined to set the practical lower limit of age detection at about 10^6 yr, while this possibility remains. This age corresponds to measuring $30–40 \times 10^{-9}$ gm of A^{40}, the amount obtainable from some 10 gm of sylvite, KCl.

It is necessary to make a few remarks regarding the discrepancy between expected age, about 10^8 yr, and measured age, 6×10^7 yr. The sample crystals were small with some tendency to crumble, and argon could possibly have escaped before analysis began. Most recent measurements of potassium-containing minerals have shown about the same amount of discrepancy, suggesting a source of systematic error. Since this examination was begun Wasserburg and Hayden (*6*) have demonstrated that it is difficult, but certainly possible, to insure complete collection of argon from minerals.

It would appear from our own work that adsorption of the gas on surfaces is the most probable cause of inefficient collection. A monomolecular layer of argon corresponds to about 0.25×10^{-4} cm^3 per cm^2 at standard temperature and pressure. The nature of the crystal and quartz surfaces may be such that effectively large areas are available as adsorption sites after the argon gas has been liberated. Previous outgassing does not improve matters in this respect. Some further adsorption studies are required, but in any event the relative values should prove reliable, and a correction factor applied to these should yield fairly accurate absolute age values.

* * *

The authors wish to thank W. G. V. Rosser for his preliminary work and for supervising the sample irradiation. They are indebted to the Isotopes Division at AERE, Harwell, for their generous cooperation in the experiment. One of us (A. M.) would like to thank the University of Ljubljana for leave of absence, and Professor Peterlin for his cooperation. Thanks are due to J. Kennedy for his work on the quartz and glass apparatus. One of us (R. W. P. D.) would like to acknowledge the financial support of the Department of Scientific and Industrial Research.

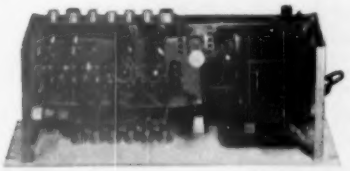
BIBLIOGRAPHY

1. R. D. Russell, H. A. Shillibeer, R. M. Farquhar, A. K. Mousuf, *Phys. Rev.* **91**, 1223 (1953)
2. A. K. Mousuf, *Phys. Rev.* **88**, 150 (1952)
3. M. C. Inghram, H. Brown, C. Patterson, D. C. Hess, *Phys. Rev.* **80**, 916 (1950)
4. L. T. Aldrich, A. O. Nier, *Phys. Rev.* **74**, 876 (1948)
5. S. C. Curran, *Quart. Revs. London* **7**, No. 3, 1 (1953)
6. G. J. Wasserburg, R. J. Hayden, *Phys. Rev.* **93**, 645 (1954)

DS2 BINARY SCALING UNIT

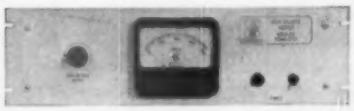
Front View

Top View



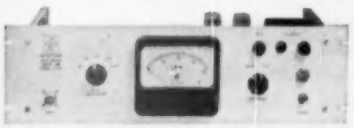
DS2 Binary Scaling Unit

The above top view shows the connectors which allow easy integration of units. On the DS2 Binary Scaler there are connectors for (1) high voltage input, (2) pulse input from another scaling unit, (3) pulse output to oscilloscope and other parallel instruments, (4) power and input connector for pre-amplifier or scintillation counters, (5) scaler control panel, (6) positive pulse output for driving register, (7) negative pulse output to drive other succeeding scaling units.



DV1 Regulated High Voltage Supply

500-2000 volts continuously variable, negative ground, regulation 0.1% at 1 ma at 2000 volts. Chrome-plated chassis with baked enamel panel, large 4½" meters. All tubes operate well within their maximum ratings. All high-voltage transformers are hermetically sealed. Output terminals are dual, for use with coincidence circuits.



DM1 Counting Rate Meter Unit

A precision instrument with full scale ranges of 200, 600, 2000, 6000 and 20,000 CPM and adjustable input sensitivity. Connectors on rear for (1) a high voltage supply, (2) parallel measuring equipment, such as a scaler, aural monitor, or oscilloscope, (3) any commercial recorder, such as the Model DW7 and (4) a pre-amplifier or scintillation counter.

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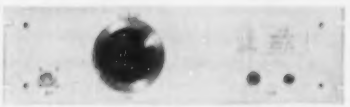
an affiliate of Borg-Warner

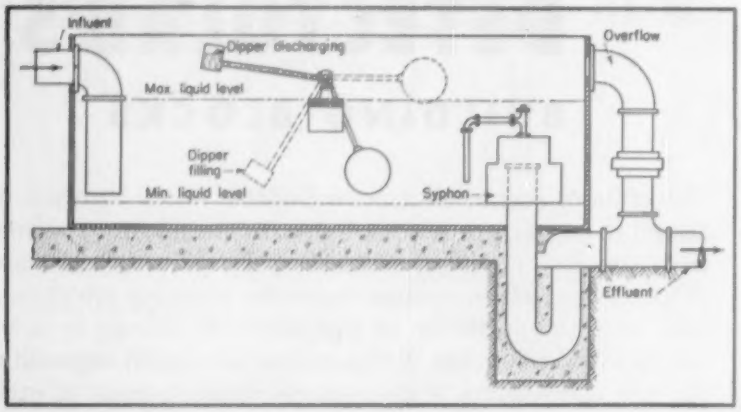
DZ16 Precision Pulser

A precision voltage pulse generator constructed on a single panel. Pulse height is variable over 5 ranges (1, 3, 10, 30 and 100 mv.) with each range divisible into 1,000 parts by a 10 turn helical potentiometer. Output pulse, either positive or negative, has a rise time of less than 10^{-8} seconds. The decay time is 350 microseconds.



DA3 Linear Pulse Amplifier

This amplifier is designed for amplifying small pulses from a scintillation counter, proportional counter or similar device, to a level where the pulses can be seen on an oscilloscope and counted with a scaler or counting rate meter. The DA3 Linear Pulse Amplifier is a complete instrument in itself and may be connected to other instruments other than associated "Building Blocks."



PROPORTIONAL SAMPLER for liquid wastes

Proportional Liquid Sampler

By JOHN M. RUDDY
Architectural Planning Division, Brookhaven National Laboratory Upton, New York

To regulate liquid wastes, which actually are or potentially may be contaminated with radioactive or poisonous materials, requires a reasonably accurate knowledge of the type and quantity of the substances involved. Adequate control of these wastes can be provided by proportional sampling of the flow and, based on the potential hazard involved, they can be discharged to holdup tanks or directly to the sewer. The proportional sampler described here is adaptable for use where low and intermittent gravity flow is a problem.

As an approach to this problem of sampling, several types of commercial gravity-flow-controlled equipment were investigated, and the best one for flows under 10 gal/min was selected for trial. This unit would not operate properly under 1 gal/min, however, and at higher rates it occasionally stopped from small amounts of foreign matter in the meter control line. As the flow from laboratory sink drains is variable, the wastes therefore often trickled through for hours without being sampled. This fact and several years experience provided a better definition of the conditions of operation and data with which to develop an effective proportional sampler for variable low flows.

From this data, the following general design criteria were established for a proportional, gravity-flow, liquid-waste sampler for chemical, biological, and medical laboratories using radioisotopes:

1. Accurate (±5%) foolproof operation gravity flows between 0 and 10 gal/min.
2. Rugged, simple construction.
3. Ease of attendance.
4. Self-powered, if possible.
5. Economical initial cost (less than $200).
6. Maximum flexibility of size and installation.
7. Minimum hydraulic gradient loss.
8. Ratio of sample to total effluent of 2 cm³/gal (about 1 to 1,900).
9. 50-gal tank working capacity.

To evaluate these design criteria, a pilot model float-actuated sample dipper in a self-syphoning tank was engineered, built, and installed on the effluent line of a chemical laboratory hot cell.

The sampler consists of a 100-cm³ dipper on one end of a hollow arm with a ball float fixed on the opposite and heavier side; the entire unit rigidly pivots on a hollow shaft mounted across a self-syphoning receiving tank. As the tank fills, the float raises, pushing the dipper under the surface, filling it and part of the hollow shaft with 100 cm³ of the liquid waste. Upon filling to 50 gal, the tank self-syphons; the heavier float end raises the dipper, discharging all the fluid collected through the hollow arm and hollow shaft to a sampling container. This cycle repeats as rapidly as required and is accurate for flows where the influent rate is not in excess of 10 gal/min (20% of the effluent rate of 50 gal/min when syphoning). Where hydraulic gradient or flow is not satisfactory for self-syphoning, a sump-type pump can and has been used to empty the tank when the 50 gal mark has been reached. The final precise adjustment of dipper quantity is made by notching the cup lip or by drilling holes. This method is also used to change the ratio to a higher one, such as 1 cm³ per 50 gal.

The tank design details provide a mounting bracket for an electric motor-driven agitator in case the type of effluent requires this, which would be started and stopped by means of microswitches actuated by the float arm or shaft. However, there has been no need as yet for agitation at six installations that have been in operation for several years.

The present sampler mechanism is made of brass with stainless steel hardware, but it can be made of any material depending on waste to be sampled. The tank is fabricated of ¼-in. steel, welded, and with bituminous coating inside and out. The automatic syphon is a standard commercial plumbing item and the sample container is usually a 5-gal glass jug. All sampler installations are preceded by neutralizing tanks to reduce acid conditions. With the exception of minor clogging at the biological laboratories, due to organic matter in the waste, all sampler installations have operated effectively and as intended at all type of laboratories and at a "hot" laundry. At biological laboratories it would be desirable to have, in addition to neutralizing tanks and preceding them, some type of coarse screen to remove organic matter larger than ½ in.

* * *

This work was performed under contract to the U. S. Atomic Energy Commission.

How Drill-Hole Diameter Affects Gamma-Ray Intensity

By SEYMOUR C. HYMAN,* BERTRAM MINUSHKIN, and JEREMIAH CERTAINE
Nuclear Development Associates, Inc.
White Plains, New York

The gamma-ray intensity in a cylindrical hole in a radioactive ore body is shown to be independent of hole size in this article. The experiments and confirming theory are presented.

Fearon (*1*) has shown that intensity should be independent of hole size and shape, but reservations are sometimes expressed (*2*). Sakakura has indicated that gamma-ray intensity should increase slightly with increasing hole diameter (*3*). He proposes that the intensity $= C(1 + Ka^n)$, where a is the hole diameter and C, K, and n are constants. The present work shows that gamma-ray intensity should be independent of hole size.

Experiment

The detector used was a scintillation-counter probe. Its angular sensitivity was measured with a small source and is shown in Fig. 1. Measurement of the azimuthal sensitivity in the horizontal plane from 0 to 360 deg showed no variation. Figure 2 shows a check made of the applicability of the inverse square law to the probe.

With these data it was possible to compute the response expected from points on a cylindrical locus. The calculated intensities agreed well with data obtained experimentally from a source placed 12 in. horizontally from the probe and at various vertical distances.

An experiment was performed to determine the minimum thickness of ore needed to establish full gamma intensity in the hole. Mock drill holes were made at the center of a 34-in.-high 22-in.-diameter drum by filling uranium-bearing ore around a thin galvanized iron sheet rolled into a cylinder. G-M and ratemeter readings were taken inside the holes with and without the drum being surrounded by six additional ore-filled drums. No effect was observed on 2 and 4-in. holes, but a 12-in.-diameter hole having a 5-in. wall showed a sharp increase (from 0.13 to 0.22 mr/hr) when the six drums were placed in position. It was concluded that a 10-in. wall of ore was effectively infinite within the sensitivity of the G-M probe used. This is reasonable since 10 in. of ore will absorb 95% of 2-Mev gamma rays. For the experiments on the effects of hole size a 12-in. wall was used.

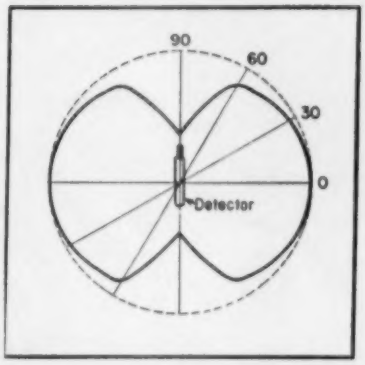


FIG. 1. Angular sensitivity of scintillation probe; note low relative sensitivity at high angles

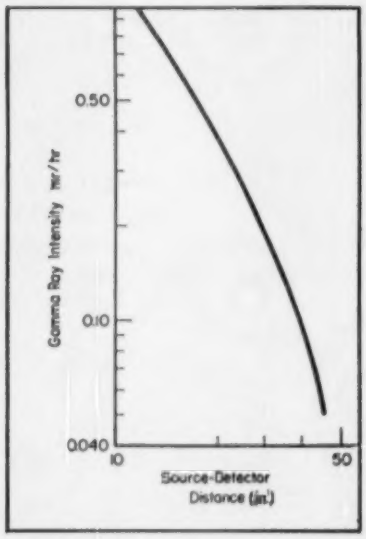


FIG. 2. Result of check of inverse-square response of probe and source used in measuring angular response of Fig. 1; note that initial slope is only 1.7

To isolate the effect of hole diameter on radiation intensity we had to establish a constant angle of view for the probe. It was also necessary to account for the varying contribution due to varying thickness of radiating ore by keeping the wall thickness constant.

Figure 3 shows the experimental arrangement. It is evident that θ is the true angle of view. When varying the radius of the hole, θ was kept constant at 54 deg by changing the height, H.

Using the constant-angle-of-view arrangement, measurements were made of the radiation intensity as a function of hole diameter. The results, in the table, summarize many individual readings all constant within 3%. Intensity changes only 5% for a change in hole diameter from 2 to 12 in. (a factor of 6), demonstrating that radiation intensity *is* independent of the hole size. The small remaining differences may well result from variations in ore packing from one hole to the next.

Mathematical Analysis

Given a hole (spherical or infinite cylindrical) with walls of interior radius a and exterior radius b containing radiating material, attenuated at the rate k cm^{-1} and of intensity I produced by unit source strength per unit volume at unit distance, then the radiation at the center of the hole is

$$I(a,b) = \int I\, e^{-k(PQ)} d\, V/(OQ)^2$$

Radiation Level in Three Holes

Ore-layer dimensions		*Hole*		
		2 in.	*4 in.*	*12 in.*
Diameter (in.)	*Total height (in.)*	*Radiation level (mr/hr)*		
26	25¼	0.197		
28	28		0.208	
36	39	0.223	0.230	0.211

* Also, Department of Chemical Engineering, City College of New York.

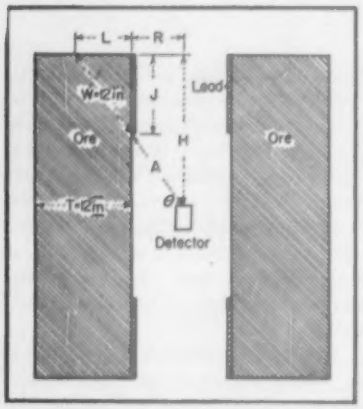


FIG. 3. Experimental geometry insures a constant angle of view. Angle θ is bounded by lines that each have 12-in. length of intersection with the ore layer. Ore region bounded by LJW is: less than full thickness, at high angle (low instrument sensitivity), farthest from detector, and shielded by lead sheet. Thus its contribution to detected intensity is small. This was also demonstrated experimentally

assuming isotropy and the inverse-square law. We show that $I(a,b)$ is a function only of the wall thickness $b-a$ and, further, is independent of the size of the hole for infinitely thick walls. We also give an expression for $I(a,b)$ in terms of the quantity $k^* \equiv k(b-a)$, which allows one to calculate $I(a,b)$ very easily for small k^*.

Spherical hole. For this integration we use an elemental spherical shell of volume $4\pi r^2 dr$. Then $(OQ) = r$, $(PQ) = r - a$ (Fig. 4), and

$$I(a,b) = 4\pi I e^{ka} \int_a^b e^{-kr}\,dr$$
$$= (4\pi I/k)(1 - e^{-k^*})$$
$$= 4\pi I(b-a)\left[1 - k^* \sum_{n=0}^{\infty} (-k^*)^n/(n+2)!\right]$$

Clearly $I(a,b)$ is a function of $b-a$ only while $I(a,\infty) = 4\pi I/k$, independent of a.

Cylindrical hole. For this integration we use an elemental ring of volume $2\pi r dr dz$. Then $(OQ) = \sqrt{r^2+z^2}$ and $(PQ) = (r-a)(\sqrt{r^2+z^2}/r)$ (Fig. 5) and

$$I(a,b) = 4\pi I \int_a^b r\,dr \int_0^{\infty} dz\, e^{-k(\sqrt{r^2+z^2}/r)(r-a)}/r^2+z^2$$

Substituting $z = r\tan\theta$ and changing the order of integration

$$I(a,b) = 4\pi I \int_0^{\pi/2} d\theta \int_a^b e^{-k(r-a)\cos\theta}\,dr$$
$$= (4\pi I/k)\int_0^{\pi/2} d\theta(1 - e^{-k(b-a)\cos\theta})\cos\theta$$
$$= (4\pi I/k)\left[1 - \int_0^{\pi/2} \cos\theta e^{-k^*\cos\theta}\,d\theta\right]$$

Letting $u = \sec\theta$, one obtains for the integral in the preceding equation

$$C = \int_0^{\pi/2} \cos\theta e^{-k^*\cos\theta}\,d\theta$$
$$= \int_1^{\infty} (du/u^2\sqrt{u^2-1})\,e^{-k^*u}$$

Since $1/u^2 = \int_0^{\infty} te^{-tu}\,dt$ and the modified Bessel function

$$K_0(a) = \int_1^{\infty} (du\,e^{-au})/\sqrt{u^2-1}$$

we obtain, using a dummy variable, t,

$$C = \int_0^{\infty} t\,dt \int_1^{\infty} du\,e^{-(k^*+t)u}/\sqrt{u^2-1}$$
$$= \int_0^{\infty} tK_0(k^*+t)$$

Now

$$C = \int_0^{\infty} (k^*+t-k^*)K_0(k^*+t)\,dt$$
$$= \int_{k^*}^{\infty} vK_0(v)\,dv - k^* \int_{k^*}^{\infty} K_0(v)\,dv$$

where $v = k^* + t$. Since $(vK_0'(v))' = vK_0(v)$ and $K_1(v) = -K_0'(v)$, then

$$C = \int_{k^*}^{\infty} (-vK_1(v))'\,dv - k^* \int_{k^*}^{\infty} K_0(v)\,dv$$

Hence

$$C = k^*K_1(k^*) - k^*\pi/2 + k^* \int_0^{k^*} K_0(v)\,dv$$

since

$$\int_0^{\infty} K_0(v)\,dv = \int_0^{\infty} dv \int_1^{\infty} e^{-vu}\,du/\sqrt{u^2-1}$$
$$= \int_1^{\infty} du/u\sqrt{u^2-1} = \text{arcsec } u\Big|_1^{\infty} = \pi/2.$$

The functions $K_0(v)$ and $K_1(v)$ are extensively tabulated and are asymptotic to $e^{-v}\sqrt{\pi/2v}$ for large v. For small values, on the other hand, they become indefinitely large and the following expansions (*4*) are of use.

$$1 - k^*K_1(k^*)/k^* = \sum_{n=1}^{\infty} [nT_n(k^*) - 1/2](k^*/2)^{2n-1}(1/n!)^2 \equiv S(v)$$

$$\int_0^{k^*} K_0(v)\,dv = 2\sum_{n=0}^{\infty} [1/(2n+1)][T_n(k^*) + 1/(2n+1)](k^*/2)^{2n+1}(1/n!)^2 \equiv I(v)$$

where $T_{n+1}(v) = T_n(v) + 1/(n+1)$ and $T_0(v) = 0.11593 - \ln v$.

We may now express our result as

$$I(a,b) = 4\pi I(b-a)[\pi/2 + S(k^*) - I(k^*)]$$

Conclusions

There is no effect of hole size on gamma radiation intensity for holes of 2-in. to 12-in. diameter. The geometry used in this experiment gave readings due to change in hole diameter only, since angle of view and wall thickness were held constant.

For a radioactive ore consisting primarily of silica, a wall thickness of 10 in. acts as an infinitely thick radiator.

Under assumptions of isotropy and the inverse-square law, the mathematical analysis shows that radiation intensity is independent of hole size for spherical and cylindrical holes.

* * *

We acknowledge the cooperation of R. S. Foote and H. LeVine of the AEC in making the scintillation counting instrument available to us.

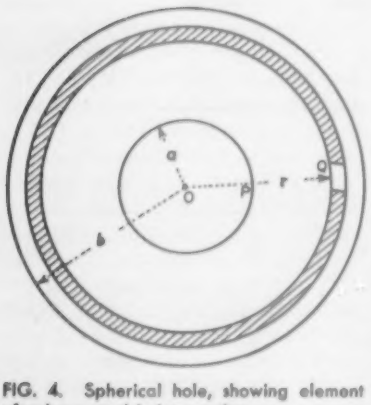


FIG. 4. Spherical hole, showing element of volume used in integration

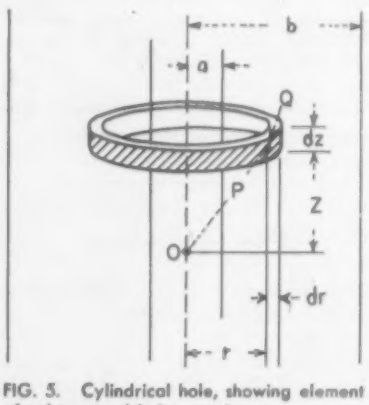


FIG. 5. Cylindrical hole, showing element of volume used in integration

BIBLIOGRAPHY

1. R. E. Fearon, NUCLEONICS **4**, No. 4, 67 (1949)
2. Private communications
3. A. Y. Sakakura, TEM-306 (1951)
4. S. C. Hyman, B. Minushkin, J. Certaine, NDA 2-13 (Nuclear Development Associates, White Plains, New York, 1954); report on which this article is based

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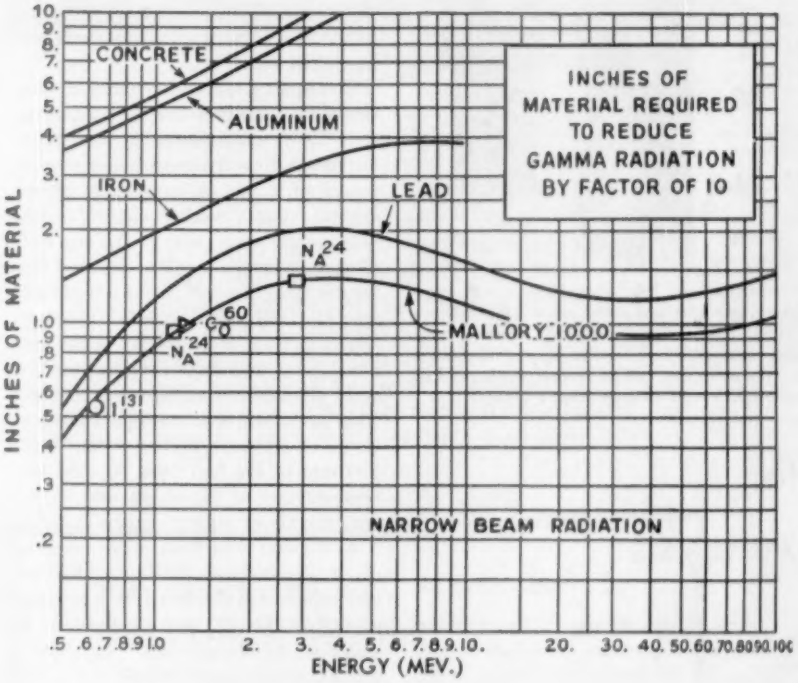

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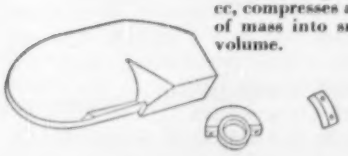

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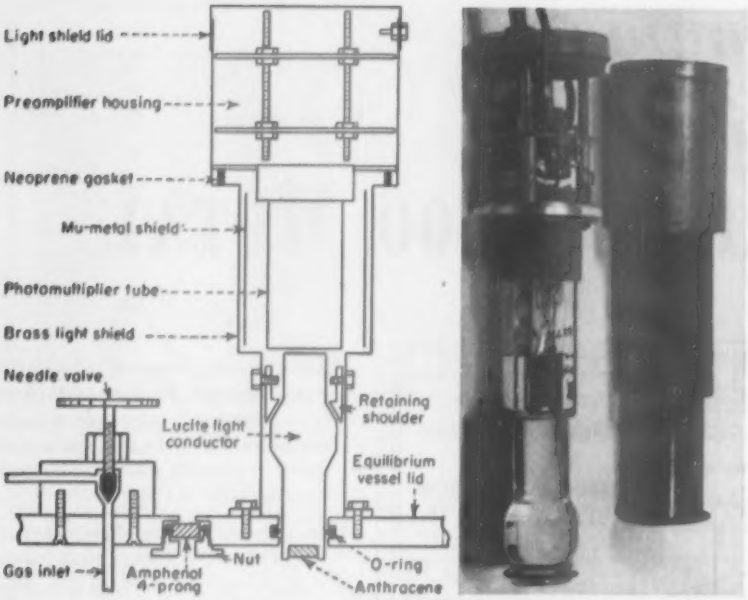

FIG. 1. Counting assembly is attached to pressure-cell lid. Cell, coated with black Tygon paint, is 3-in.-dia Pyrex pipe, 7⅝ in. long; gas inlet and outlet are on stainless-steel lid. Vapor in cell is stirred with magnetic Teflon-clad rod and externally mounted magnetic stirrer. Counting assembly (above and right) utilizes 1-in.-dia, ¼-in.-thick anthracene crystal sealed in 1¾-in.-dia Lucite rod. Phosphor and cell-lid temperatures are kept above dew point of water by Variac-controlled 250-watt infrared heat source

Scintillation Counter for Vapor-Phase Analysis

By K. L. MAI* and A. L. BABB
Department of Chemical Engineering
University of Washington
Seattle, Washington

Several techniques utilizing radioisotopes have been described for continuous analysis of liquid or vapor phases (*1–8*). This paper describes the application of a scintillation counting technique (*9*) to the continuous analysis of a vapor phase containing CO_2, H_2S, and water.

This method was developed to facilitate vapor-liquid measurements on the system Na_2O-CO_2-H_2S-H_2O (*10*). In this system, the liquid phase contained sodium sulfide, carbon dioxide, and hydrogen sulfide dissolved in water, and the vapor phase contained carbon dioxide, hydrogen sulfide, and water. At conditions of equilibrium, the composition of the liquid phase could be continuously determined from conductivity and *p*H measurements. To establish the composition of the vapor at equilibrium, however, either the partial pressure of carbon dioxide, P_{CO_2}, or the partial pressure of hydrogen sulfide, P_{H_2S}, had to be known in addition to the total pressure, π, which was measured, and the partial pressure of water, P_{H_2O}, which was calculated from Raoult's law. Moreover, to obtain vapor-liquid equilibrium data over wide ranges of temperature and pressure, it was desirable to have a method whereby either P_{CO_2} or P_{H_2S} could be determined continuously without disturbing the system by withdrawing samples of the vapor for analysis. As a result, a scintillation counting technique was adopted so that by using hydrogen sulfide tagged with S^{35} in the vapor, P_{H_2S} and hence the composition of the vapor could be obtained from a measurement of the total radioactivity of the vapor.

In preparing the radioactive vapor, 8 mc of sulfur-35 in the form of hydrogen sulfide (5 cm^3) were obtained through Tracerlab, Inc. This material was diluted with about 8 moles of hydrogen sulfide (99.7% purity) by evacuating a 1,200-cm^3 stainless-steel cylinder and then transferring first the tracer and then the diluent over into the cylinder by means of dry ice-acetone refrigeration. The hydrogen sulfide thus obtained contained 4.46×10^{-5} mc per cm^3 of S^{35} at standard conditions of temperature and pressure. The carbon dioxide used had a purity of 99.8%.

Calibration Experiments

The optimum operating voltage for the scaler and scintillation head, determined with a standard cobalt-60 source, was 1,260 volts, d-c.

To obtain a calibration curve of cpm versus P_{H_2S}, the pressure cell was placed in a thermostat, evacuated, and then background counts were taken over a period of 2 hr. Although the background counts varied slightly with temperature, they were of the order of 80 cpm. Then a small amount of the tagged hydrogen sulfide was introduced into the cell and the total pressure (P_{H_2S}) and the radioactivity of the gas phase, cpm, were recorded after steady-state conditions had been established. This procedure was continued until a range of pressures of H_2S from 50 to 800 mm of Hg had been covered for temperatures of 20, 35, 50, and 65° C over the above pressure range.

At the end of each series of runs at a given temperature, the tagged hydrogen sulfide was displaced by a stream of carbon dioxide and scrubbed in a cadmium sulfate solution. The background counts taken before and after each series of runs agreed within 2–3%.

Temperature effect. Since the sensitivity of the phosphor crystal and photocathode decreases with increasing temperature (*8, 11*), the calibration curves must include temperature as a parameter. To obtain calibration curves that have a uniform accuracy over a wide temperature range, the amplifier gain settings on the scaler were changed from 15% at 20° C to 20, 30, and 50% at 35, 50, and 65° C, respectively. The resulting calibration curves (Fig. 3) were corrected before each use for the S^{35} beta decay, which has a 87.1-day half-life. Over a two-month period, any one of the calibration curves could be reproduced within 2½%.

Shielding effect. To ascertain the possible shielding effect that CO_2 and H_2O molecules might have on the tagged hydrogen sulfide molecules in the vapor phase during measurement of the Na_2O-H_2S-CO_2-H_2O system, the

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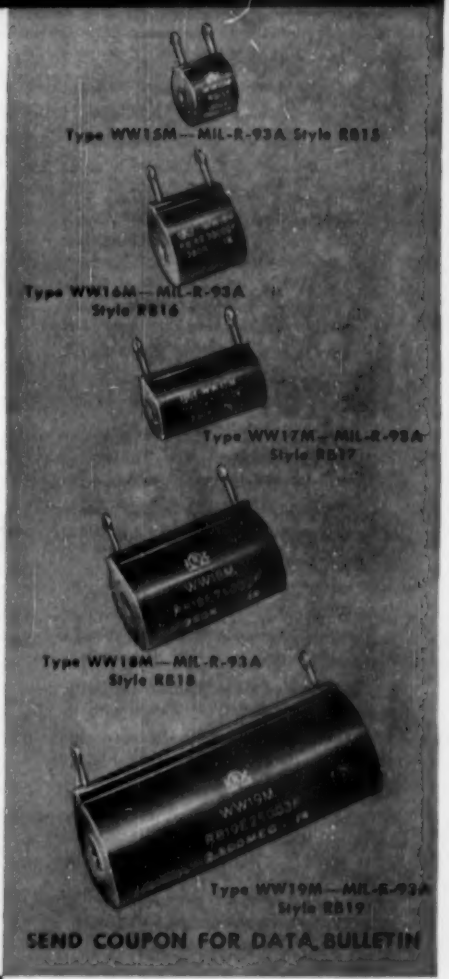
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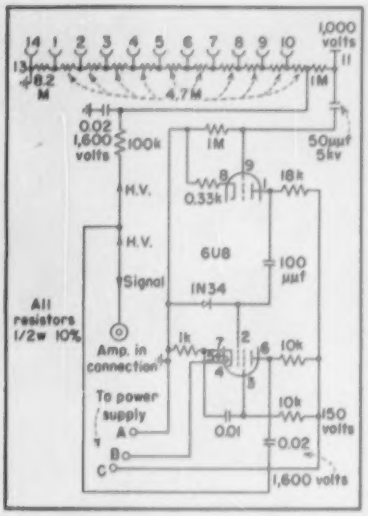

FIG. 2. Preamplifier for Dumont-6292 tube provides pulses >0.25 volts with 20-μsec duration; 150-volt d-c amplifier power supply furnishes up to 22.5 ma with 17-ohm impedance and <1.5-mv ripple when supplying 8 ma. Results are indicated on Nuclear Instrument and Chemical Corp. model 162 scaler and Streeter-Amet Co. "Ametron" automatic counter-recorder

total pressure in the cell was varied from 100 to 3,500 mm of Hg during the calibration measurements by adding carbon dioxide. The partial pressure of the tagged hydrogen sulfide and the temperature were maintained constant as the total pressure was varied. For each total pressure the radioactivity of the vapor phase, the temperature, and the partial pressure of hydrogen sulfide were recorded. By comparing these values with those given by Fig. 3, it was established that the maximum decrease in radioactivity of the vapor phase amounted to 3% when the total pressure in the cell was ten times the partial pressure of hydrogen sulfide. Moreover, the decrease in radioactivity was directly proportional to the ratio of the total pressure to the partial pressure of hydrogen sulfide so that simple corrections could be applied to the original data for this so-called "shielding" effect.

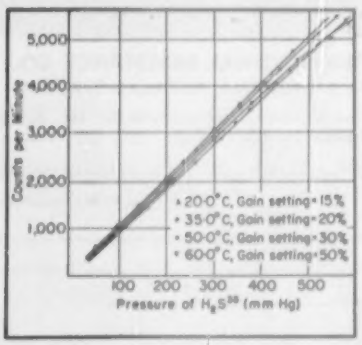

FIG. 3. Calibration curves for partial pressure of H_2S in vapor phase

Statistical accuracy. The statistical accuracy of these measurements may be determined from the following equation, which is descriptive of a Gaussian distribution, $M = 0.67(100/N^{1/2})$, where M is the percentage deviation from a mean number of counts, and N is the total number of counts taken (*12*). Thus for 5,000 counts, which was the minimum number taken for each measurement, the statistical accuracy was about 1%. With the "Ametron" recorder, however, 10,000–100,000 counts were conveniently obtained so that the statistical error was reduced to a value between 0.25 and 0.50%. The reproducibility of the experimental data obtained was better than 3% (*13*).

This method has also been successfully applied to the continuous analysis of a vapor consisting of sulfur dioxide, ammonia, and water (*14*), in which the sulfur dioxide was tagged with sulfur-35.

* * *

The authors wish to acknowledge the assistance of Mr. A. W. Wakefield with the electrical circuitry. This research was supported by a grant from the Engineering Experiment Station at the University of Washington. This article was presented in part at American Chemical Society Northwest Regional Meeting, Richland, Wash., June, 1954.

BIBLIOGRAPHY

1. H. E. Huges, J. O. Maloney, *Chem. Eng. Progr.*, **48**, 192 (1952)
2. I. Amdur, J. W. Irvine, E. A. Mason, J. J. Ross, *J. Chem. Phys.* **20**, 436 (1952)
3. K. D. Timmerhaus, H. G. Drickamer, *J. Chem. Phys.* **19**, 1242 (1951)
4. K. D. Timmerhaus, H. G. Drickamer, *J. Chem. Phys.* **20**, 981 (1952)
5. W. L. Robb, H. G. Drickamer, *J. Chem. Phys.* **19**, 1504 (1952)
6. L. H. Tung, H. G. Drickamer, *J. Chem. Phys.* **20**, 6, 10 (1952)
7. R. C. Koeller, H. G. Drickamer, *J. Chem. Phys.* **21**, 267 (1953)
8. H. G. Drickamer, K. D. Timmerhaus, L. H. Tung, *Chem. Eng. Progr.* **49**, 503 (1953)
9. J. B. Birks, "Scintillation Counters" (McGraw-Hill Book Co., Inc., New York, 1953)
10. K. L. Mai, A. L. Babb, to be submitted to *Ind. Eng. Chem.*
11. W. L. Minarik, H. G. Drickamer, *Rev. Sci. Instr.* **22**, 704 (1951)
12. D. Halliday, "Introductory Nuclear Physics," p. 207 (John Wiley and Sons, Inc., New York, 1950)
13. K. L. Mai, Ph.D. Thesis, University of Washington (1954)
14. D. T. Hayden, A. L. Babb, J. L. McCarthy, to be submitted to *Tappi*

Potentiometric Determination of Iron by X-Ray Oxidation

By MELVIN A. DEWAR and ROBERT R. HENTZ
Department of Chemistry, North Carolina State College
Raleigh, North Carolina

The oxidation of aqueous ferrous solutions and reduction of aqueous ceric solutions by ionizing radiations (*1–5*) suggests its use as a redox reagent in some analytical determinations when highest precision is not required. Fission products might be utilized in relatively simple, perhaps automatic, analytical units for routine analyses.

Because of the extensive work done on aqueous ferrous systems, the potentiometric determination of iron by X-ray oxidation was chosen for studying the feasibility of such a method.

Experimental

Reagents were: Merck reagent-grade ferrous ammonium sulfate; General Chemical reagent-grade sulfuric acid; and Merck U. S. P. sodium chloride. Water was redistilled from permanganate. Glassware was soaked in hot dichromate-sulfuric acid solution prior to use.

Irradiations were made with a GE model OX-140 industrial X-ray unit with a SP-140 tube unit. The tube was operated at 100-kv peak voltage from an unregulated supply. Ferric

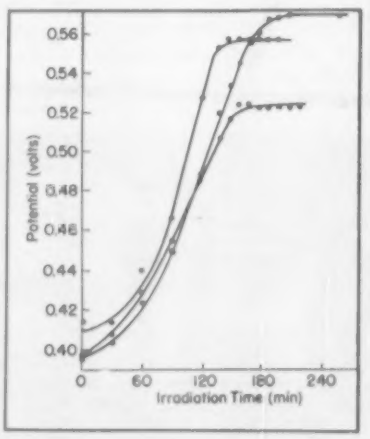

FIG. 1. Titration curves for 10^{-4}M ferrous solutions

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ion concentration was determined before and after irradiation in some experiments by its absorption at 3,050 Å with a 0.50-mm slit width. Measurements were made with a Beckmann DU spectrophotometer and hydrogen lamp and silica cells. A molar extinction coefficient of 2,200 was used. Miller and Wilkinson (*6*) list two molar extinction coefficients in this vicinity.

In initial experiments, the potentials of unstirred solutions were measured after irradiation. The potential changes were small and erratic, particularly beyond the dose at which complete oxidation should have occurred. Prolonged stirring of a sample after irradiation, up to 45 min after long exposures, resulted in an increase in potential to a constant value. Plots of these limiting values against irradiation time gave good titration curves. This was at first attributed to a post-irradiation effect (*2, 4*) in the low concentration range of these experiments, $\sim 10^{-4} M$. However, spectrophotometric measurements showed no increase in ferric ion concentration after prolonged stirring. Plots of ferric ion concentration in the unstirred solutions vs irradiation time were linear to the point of complete oxidation and horizontal beyond. The effect is therefore in the potential measurement and possibly due to peroxide or gas formation.

For samples continuously stirred during irradiation, absolute values of the potential were affected slightly by rate of stirring. Since this rate was constant during an irradiation, the curves were shifted for different stirrer speeds along the potential axis without affecting the reproducibility of the time for complete oxidation.

Therefore, in all later work, a 10-ml sample in a 50-ml beaker containing a glass-enclosed iron rod was placed on a magnetic stirrer under the X-ray tube window. A lead-shielded saturated calomel reference cell was connected to the sample by a 3% Agar-30% potassium chloride salt bridge. A platinum electrode was placed in the solution and the connecting leads brought out to a Leeds and Northrup type K potentiometer. The solution was then irradiated with continuous stirring and periodic potential measurement. Geometry and tube current were maintained constant and time of exposure was taken as a measure of dose.

Blank runs showed atmospheric oxidation of ferrous ion to be negligible within the limits of accuracy. All ferrous solutions were $\sim 10^{-3} M$ in sodium chloride, to eliminate any effect of dissolved organic matter, and $0.8 N$ in sulfuric acid.

Results

The number of ferrous ions oxidized per unit energy absorbed by a solution (yield) is independent of ferrous ion concentration over the range $0.1\text{–}5 \times 10^{-3} M$. A potentiometric titration curve should be obtained similar to that for a standard redox titration up to the stoichiometric point. An equilibrium exists in the chemical system that produces a symmetrical curve beyond the stoichiometric point. However, the irradiated-system titration curve probably becomes horizontal at a lower limit of ferrous ion concentration. The stoichiometric point is then at the intersection of the extrapolated horizontal and sharply rising parts of the curve. Some typical analyses are shown in Fig. 1.

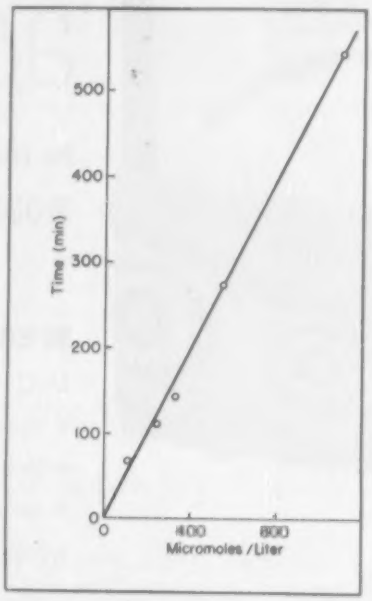

FIG. 2. Time for complete oxidation vs initial ferrous ion concentration

If yield is constant to the ferrous ion concentration at which oxidation ceases, a calibration curve of stoichiometric dose versus initial ferrous ion concentration as shown in Fig. 2 should be linear with an abscissa intercept at the lower limit of ferrous ion concentration. The equation of this line would be

$$D = (\mathrm{Fe}_i - \mathrm{Fe}_f)/Y$$

where i stands for initial, Y for yield, D for stoichiometric dose, and f for limit or final.

It is more likely that the yield decreases at very low ferrous ion concentrations. The calibration curve would then be linear in the high concentration range and curve upwards at lower concentrations. If initial ferrous ion concentrations are sufficiently large relative to the concentration at which yield decreases appreciably, the dosimetry yield may be used in place of a calibration curve.

The calibration curve of Fig. 2 was obtained by diluting $1.1 \times 10^{-2} M$ stock solution of ferrous ion to solutions of 0.5, 0.3, 0.2, and 0.1 the original concentration. Within the limits of error, the straight line suggests that oxidation proceeds with constant yield to a ferrous ion concentration below $10^{-4} M$. The average time required to oxidize 10 $\mu M/l$ is 4.73 ± 0.18 min, the usual reproducibility found in this work. A yield of 20 $\mu M/l/1{,}000$ r (*3*) gives the dose rate used as 108 r/min.

Conclusions

The equipment available for this study imposed several limitations on the precision that could be eliminated with a high-intensity gamma source. Continual manual adjustment of the X-ray tube current was necessary to maintain reasonably constant dose rate. The available dose rate limited the maximum ferrous ion concentration that could be oxidized in a reasonable time to $10^{-3} M$. Better precision should be possible at the higher concentrations permitted by a gamma source. However, care must be exercised to insure that oxygen is not exhausted from the solution when concentrations greater than $10^{-3} M$ are used, corresponding to doses in excess of 50,000 r (*5*). Use of a recording potentiometer would give continuous titration curves and permit more accurate location of the stoichiometric point.

The system dealt with in this study was an ideal one. Application to more complex solutions is necessary before the practicality of the method can be established.

* * *

This article is based on a thesis submitted by M. A. Dewar to the Department of Physics of the North Carolina State College in partial fulfillment of the requirements for the degree of Master of Science in Nuclear Engineering.

BIBLIOGRAPHY

1. N. Miller, *J. Chem. Phys.* **18**, 79 (1950)
2. C. J. Hochanadel, J. A. Ghormley, *J. Chem. Phys.* **21**, 880 (1953)
3. S. Davison, S. A. Goldblith, B. E. Proctor, M. Karel, B. Kan, C. J. Bates, NUCLEONICS **11**, No. 7, 22 (1953)
4. H. A. Dewhurst, *Trans. Faraday Soc.* **49**, 1174 (1953)
5. J. Weiss, NUCLEONICS **10**, No. 7, 28 (1952)
6. N. Miller, J. Wilkinson, *Discussions Faraday Soc.* **12**, 50 (1952)

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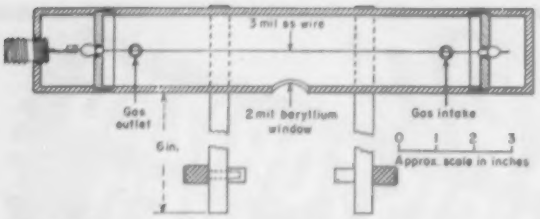

FIG. 1. Source supports move vertically on Micarta detector stand (low-atomic-number Micarta prevents spurious X-rays and insulates detector from ground to permit positive or negative high-voltage supplies). Detector, aluminum construction, has beryllium window to extend useful range to low photon energies

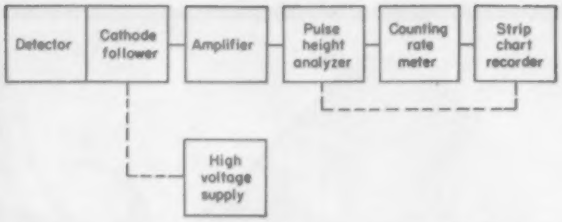

FIG. 2. A-1 amplifier (Atomic Instrument Co., model 204C) operates at full gain using 16-μsec input time constant and 100-$\mu\mu$f capacitor shunting 15,000-ohm feedback resistor; risetime is about 1 μsec. Detector and amplifier parameters minimize pulse-height dependence on orientation of ionization path (9)

Proportional Gamma Spectrometer

By D. G. MILLER
Hanford Atomic Products Operation
General Electric Company
Richland, Washington

A number of workers (*1–6*) have shown that the gas-filled proportional counter offers a very useful and convenient method for investigating X- and gamma radiations in the energy region up to 100 kev. The proportional counter has been employed for determining low-energy beta spectra (*1*), in coincidence studies (*2*), in investigating the low-energy radiations from Pu^{239} and U^{233} (*3*), in studies of *K* and *L*-capture X-radiation (*4*), and as a detector in gamma photometry (*7*). Additional applications of the proportional counting technique may be found in extending the usefulness of gamma spectroscopy, as applied to the analysis of radionuclide mixtures (*8*), to the energy region below 100 kev, in the analysis of low-energy X- or gamma radiations in the presence of higher energy components, and in the quantitative analysis of mixtures of transuranium isotopes. Although the rather modest resolving power of this instrument limits its applicability in many studies, its simplicity and adaptability recommend its use for many analyses in the low-energy region. A spectrometer constructed in this laboratory (Figs. 1–3) is evaluated here.

In the recording system shown in Fig. 2, a single-turn, 359-deg potentiometer, connected through a gear train to the chart drive of the Brown strip-chart recorder, controls the base line of the single-channel differential-pulse-height analyzer (Atomic Instrument Co.). The chart drive gives a 12-in. scan of a 100-volt pulse-amplitude array in 20 min; a 1-volt slit width was used for the spectra shown here.

The spectrometer characteristics were investigated using three different gas mixtures: argon plus 2% carbon dioxide, argon plus 10% carbon dioxide, and argon plus 10% methane.

In addition to the relative values indicated in Fig. 4, an absolute value for the gas-amplification factor is of interest. With 29.5 ev as the energy expended by a photoelectron in producing an ion pair in argon, the absolute gas amplification factor at 2,200 volts for the argon-10% methane mixture is calculated to be approximately 200.

The slope of Fig. 4 can be increased by using smaller collecting-electrode diameters or decreased by using larger diameters. The optimum diameter depends on a number of variables: (1) The gas amplification desired—which in turn is dependent upon the external (electronic) amplification available. Large gas-amplification factors (>1,000) should be avoided since the associated positive ion cloud distorts the pulse-amplitude distribution with a resultant loss in resolution and stability. (2) The collector potential—which must be sufficiently low to eliminate insulation problems. (3) The high voltage stability requirement; its importance is indicated by Fig. 4. A 0.1% change in collector potential at 2,200 volts, using the argon-10% methane mixture, results in a 1.5% change in pulse height.

The table compares the photopeak resolution obtained for four isotopes that decay by electron capture and emit the characteristic X-radiation of the daughter isotope. Resolution is defined as the percent photopeak width

Percent Photopeak Resolution

Source	*K X-ray energy (kev)*	*Mount*	*2% CO_2-argon*	*10% CO_2-argon*	*10% CH_4-argon*	*96% helium-4% isobutane*
Fe^{55}	5.9	Fe° on 0.03 in. Al	23.1	25.6	19.5	29.3
Zn^{65}	8.0	Zn° on 0.03 in. Al	29.0	27.4	27.4	
Sc^{75}	10.7	SeO_2 on 1-mil Teflon	24.7	23.1	18.5	
Sn^{113}	24.1	$Sn(NO_3)_2$ on 1-mil Teflon	19.0	18.0	14.1	

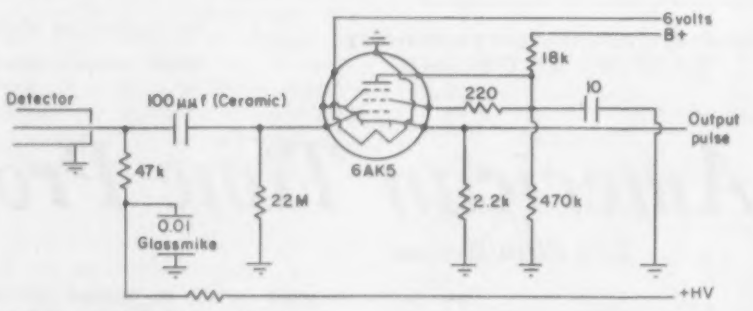

FIG. 3. Cathode-follower circuit

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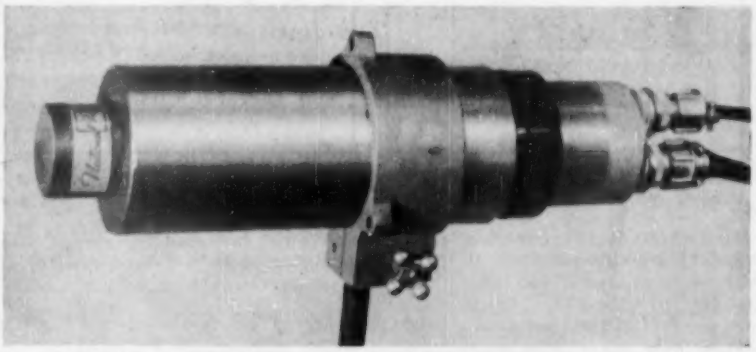


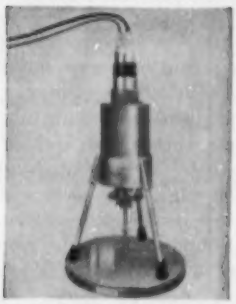
COLLIMATOR ATTACHMENT

Model LC-2 Collimator Attachment mounted on scintillation counter. Includes large, one-inch diameter by one-inch long sodium iodide crystal for high sensitivity. Highly directional lead shield in front and behind crystal insures low background. Convenient adjustable clamp and stand.

WELL TYPE SHIELD

Model LW-2 Shield Attachment holds scintillation counter and two-inch diameter well-type sodium iodide crystal. Provides full two inches of lead shielding in every direction, including below counter. Low background, high sensitivity. Crystal or counter instantly removable.

SAMPLE CHANGER



Model SM-2 Manual Sample Changer Attachment holds scintillation counter and crystal detectors. Provides two inches of lead shielding. Holds standard planchets.

A Complete Assortment of Crystal Radiation Detectors for Every Counting Need

Hermetically sealed, thin-walled containers. Optical glass windows. Transmits ultra violet. Interchangeable, permanent, light tight.

ALPHA COUNTER

Alpha particle counter. Light tight, insensitive to other radiations.

Hermetically sealed sodium iodide crystal. Best for gamma rays.

SODIUM IODIDE CRYSTAL

Sodium iodide, well type crystal. Has ¼ inch diameter by 1½ inch deep well.

WELL TYPE CRYSTAL

BETA COUNTER

Thin Stilbene single crystal, sensitive principally to Beta rays.

Also in sealed mountings, there are other Sintilon brand detectors which are interchangeable with the ones illustrated.

- Lithium iodide crystal neutron counters.
- Boron loaded plastic, slow neutron counters (contains 20% boron).
- Proton recoil type, fast neutron counters.
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Send for Bulletins 10 and 11 describing these.
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Specify Sintilon® brand crystals manufactured by

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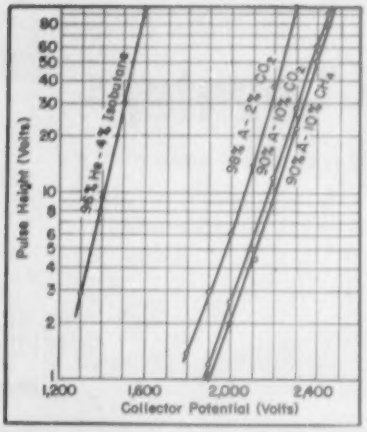


FIG. 4. Data obtained using Fe^{55} source (5.9-kev Mn K X-ray), arrangement of Fig. 1 (3-mil-diameter collector, approximately 5,600 amplifier gain), and Tektronix model 513-D oscilloscope

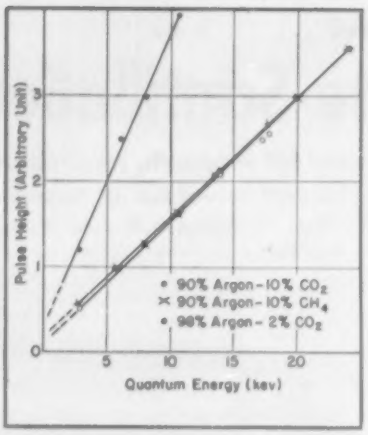


FIG. 5. Sources used for spectrometer photon-energy response were Fe^{55} and argon K X-ray escape peak, Zn^{65}, Se^{75}, Sn^{113}, Pu^{239}, Am^{241}, and K X-rays of Cu and Zr excited by Am^{241} 60-kev γ-ray (10)

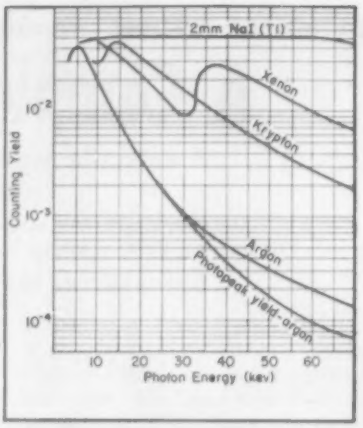


FIG. 6. Counting yield (cpm/dpm) calculated using total-gamma-absorption cross sections (13–15); argon peak calculated using only photoelectric-absorption cross section (13). Uncanned-NaI(Tl) curve calculated for same geometry (0.0496). Window dia. is 1 in.; source to window, 1 in.; source dia., ½ in.

at one-half of the photopeak's height. Here, only the relative resolution between gases is of interest since the different mounting techniques used complicate the between-source relationship.

The differences in resolution appear to be statistically significant. The improved resolution obtained using methane, rather than carbon dioxide, can probably be attributed to its lower electron-attachment coefficient.

A very significant resolution advantage is obtained using the proportional counter in place of a scintillation counter in this energy region. For example, at energies of 6 and 24 kev the resolutions obtained using a NaI(Tl) scintillation crystal are approximately 120% and 60%, respectively (12).

The spectrometer's response was linear to pulses of known amplitudes from a pulse generator. Figure 5 shows the pulse height response as a function of photon energy for this spectrometer using each of the three gases studied.

It is of fundamental importance to note that the pulse height-vs-photon energy response is linear down to at least 3 kev, which is the lowest energy investigated in the present work. The nonlinearity indicated by extrapolation of the curve below 3 kev agrees well with the work reported by Curran, Angus and Cockroft (2). This nonlinearity reflects an increase in the energy required to produce an ion pair for electrons possessing energies below the 3-kev limit. Other workers have shown that the energy expended by an electron per ion pair formed is constant for argon and also for the other noble gases from approximately 1 kev to at least 500 kev (5).

From the data presented in Fig. 6 it is seen that an energy response of particular advantage in a given application can be attained by selection of the proper counter gas. The energy response of a standard, canned NaI(Tl) crystal would drop more sharply at low photon energies than is shown in Fig. 6 due to absorption by the aluminum can.

The lower ev/ion-pair values and increased probability of photoelectric interaction characteristic of the higher atomic number noble gases are additional advantages to be realized through their use. The effect of the ev/ion-pair value on photopeak resolution is demonstrated by reference to the resolution obtained using both helium and argon (see table). The possibility of decreasing the ev/ion-pair value for a given gas, to obtain increased resolution, offers an interesting problem.

Spectra obtained are shown in Figs. 7 and 8.

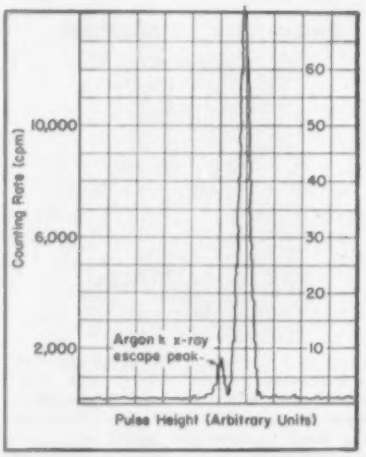


FIG. 7. X-ray spectrum of Fe^{55} K-capture source (2,175-volt collector potential). Principal peak is 5.9-kev Mn K X-ray; lower-energy peak is 3-kev K X-ray excited by photoelectric interaction of incident quanta with argon K electrons

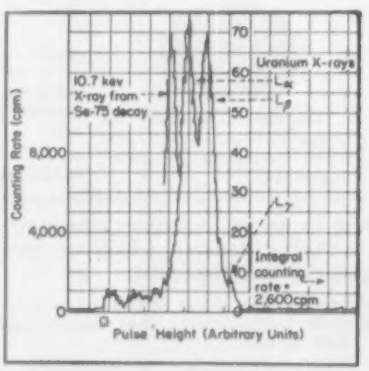

Counting Rate (cpm)
10.7 kev X-ray from Se-75 decay
Uranium X-rays
Integral counting rate = 2,600 cpm
Pulse Height (Arbitrary Units)

FIG. 8. Spectrum obtained with 60-mg Pu^{239} source (3-in. source-to-detector distance, 2,175-volt collector potential); included is Se^{75} calibration peak

BIBLIOGRAPHY

1. J. P. Mise, D. J. Zaffarano, ISC-347 (1953)
2. S. C. Curran, J. Angus, A. L. Cockcroft, *Phil. Mag.* **40**, 36 (1949)
3. D. West, J. K. Dawson, C. J. Mandleberg, *Phil. Mag.* **43**, 875 (1952)
4. G. C. Hanna, D. H. W. Kirkwood, B. Pontecorvo, *Phys. Rev.* **75**, 985 (1949)
5. S. C. Curran, *Advances in Physics* **2**, 411 (1953)
6. W. Bernstein, H. G. Brewer, Jr., W. Rubinson, NUCLEONICS **6**, No. 2, 39 (1950)
7. M. B. Leboeuf, D. G. Miller, R. E. Connally, NUCLEONICS **12**, No. 8, 18 (1954)
8. R. E. Connally, M. B. Leboeuf, *Anal. Chem.* **25**, 1095 (1953)
9. G. S. Hurst, R. H. Ritchie, *Rev. Sci. Instr.* **24**, 664 (1953)
10. G. M. Insch, *Phil. Mag.* **41**, 857 (1950)
11. D. West, P. Rothwell, *Phil. Mag.* **41**, 873 (1950)
12. G. W. Hutchinson, NUCLEONICS **11**, No. 2, 24 (1953)
13. G. R. White, NBS-1003 (1952)
14. A. H. Compton, S. A. Allison, "X-Rays in Theory and Experiment" (D. Van Nostrand Co., Inc., New York, 1935)
15. A. H. Jaffey, ANL-4875 (1952)

Advances in Applied Radiation

DEVELOPMENTS in the FIELD OF APPLIED RADIATION ENERGY, its APPLICATIONS and the APPARATUS USED TO PRODUCE IT

HIGH VOLTAGE PIONEERS LINEAR ACCELERATORS

HIGH VOLTAGE, sole manufacturer of Van de Graaff particle accelerators, has just announced the first microwave linear accelerator offered commercially in this country.

The initial model of a new line of linear accelerators to be manufactured by HIGH VOLTAGE is a radiation-producing machine designed especially for operation in the 4 to 7-million-volt range. The company will soon introduce several models of this accelerator for cancer therapy, scientific research, industrial radiography, electron-beam sterilization and radiation processing of plastics and other chemical products.

This seven-million-volt atom-smasher has been undergoing an exhaustive test program at HIGH VOLTAGE's plant for several months. Excellent performance is reported by the company's physicists and engineers. Its introduction will fill a long-felt need for a compact, flexible radiation machine capable of operating efficiently in this particular high energy range. Adapted to cancer therapy, it will supplement the 2-million-volt Van de Graaff X-ray generator also made by HIGH VOLTAGE, nearly a score of which are now in use in hospitals both in this country and abroad.

The powerful beam of electrons produced can be used directly in the treatment of biological or chemical systems, or it can be fired onto a gold target with X-rays being produced in the collision. These X-rays have far greater penetrating power than X-rays normally used in medical therapy and industrial radiography. As an X-ray source, the new linear accelerator will produce several hundred roentgens of radiation at one meter while operating at 6 to 7 million volts. Electron beam power is approximately one kilowatt in the range from 4 to 6 million volts.

Compactness is a most important feature of the new accelerator, allowing it to be flexibly mounted at considerable distance from its radar frequency power supply and controls, and to be operated in a relatively small treatment room. This compactness and the flexibility it makes possible, together with the very high energy of the X-rays it produces, make the linear accelerator a valuable new tool, both for industry and for the battle against deep-seated cancer.

Van de Graaff Components for Britain

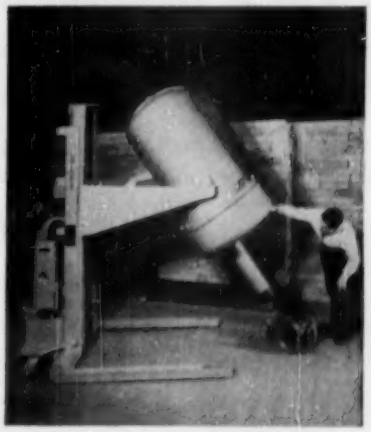
HIGH VOLTAGE has recently contracted to supply all the vital components of a huge 6-million-volt Van de Graaff accelerator soon to be located at the Imperial College, Kensington, England. The heavy metal components, including the pressure tank, will be purchased in Britain and the machine assembled there. It will be used in a program of fundamental nuclear research conducted by Prof. Samuel Devons. The 6-MeV machine will be similar to those built by HIGH VOLTAGE for Oak Ridge National Laboratory, Rice Institute and to another now under construction for Columbia University.

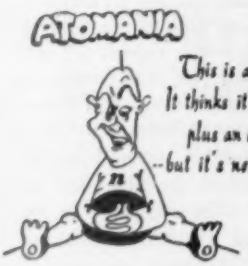
Cancer Therapy Unit to Cleveland

A two-million-volt Van de Graaff for cancer therapy will be delivered this month to University Hospitals, Cleveland, Ohio, where it will mark the first step in the expansion of the radiology department to two or three times its present size. Dr. Hymer L. Friedell, director of Radiology, will use the machine for rotational therapy, in which the patient is placed in a rotating chair and the powerful X-ray beam precisely focused on the axis of the tumor. In this way, the tumor is continuously subjected to radiation, while dosage to the skin and surrounding tissue is minimized.

Radiographic Machine Gets New Mount

The unique one-million-volt Van de Graaff X-ray generator for industrial radiography recently introduced by HIGH VOLTAGE has now been fitted with a new mount which accentuates this supervoltage machine's portability. The Lewis-Shepard Company of Watertown, Mass., has designed and built a new version of its Jack-Stacker especially for use as a carriage for this compact X-ray source. With the new mount, the machine can be moved to any part of a plant, used at any angle from horizontal to vertical, and made operative simply by plugging in a power cable. This radiographic unit is the smallest (its tank is only six feet long and 36 inches in diameter), the lightest (it weighs only 2,500 pounds) and the lowest-priced one-million-volt X-ray generator made. Its ¾ millimeter focal spot makes possible radiographs of remarkable clarity through metal sections up to five inches thick with short exposure times.





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Colloidal Gold Infusion Unit

By S. ALLAN LOUGH
Physics Laboratory
Francis Delafield Hospital
New York, New York

The colloidal gold infusion unit described here was developed to permit easy transport of the radioisotope shipping bottle, after its preparation for final use at a central distribution point, and to allow the infusion set to be readily movable to any treatment room in a hospital.

The unit (see illustration) is a modification of the arrangement described by Yalow and Cohen.* Although structurally more complex, it is believed to be easier to use and more versatile. The unit is supported on an X-ray tube stand that passes through the top and bottom plywood-reinforced shelves of an aluminum four-wheel cart.

The small shelf, *P*, bearing the shielded gold vessels, can be raised and lowered on the tube stand. Saline bottles, S_1 and S_2 (each 1,000 ml), can be raised still further with respect to the shelf by pushing the supporting rod, *R*, through the collar, then fixed with a thumb screw.

The 10-ml bottle, *GB*, containing the individual dose of radiogold as shipped by the supplier,† is shielded by 1-in. lead fitted with two lead caps. A solid cap is used for protection during transport; the other cap is provided with two holes, spaced ½ in. center to center, that pass freely a 15-gage hypodermic needle.

The dilution bottle, *DB*, is 2½ in. o.d. and 9 in. from the bottom to the lower edge of the 55/50 standard taper joint.‡ The ⅜-in. lead shield for *DB* is fitted with a divided top that swings open or closed and allows the glass tubing to pass through it when closed.¶

Administration Procedure

1. The needle-hole lead cap, dilution bottle (*DB*) with 5-ft rubber tube on air vent, syringe, 3-way stopcock and auxiliary tools are autoclaved and cooled.

2. The gold bottle is unpacked in the hot laboratory, the rubber cap is exposed, the bottle is placed in its shield and covered with the solid lead cap.

3. In the treatment room, the rubber cap of *GB* and the rim of the shield are disinfected with zephiran chloride solution, using a gauze sponge held in 9-in. sponge forceps. Then the sterile needle-hole lead cap is placed on the shield.

4. With sterile rubber gloves and a thick pad of sterile gauze, two 4-in.-long sterile 15-gage hypodermic needles are put through the needle holes and the rubber cap of *GB*.

5. A sterile Venotube§ connects one needle to inlet *A* of *DB*. A male glass adaptor on S_1 takes the female of a second Venotube, the male end of which is connected with the second needle. A 5-in. hemostat with rubber-covered jaws is clamped on the tube near S_1 and S_1 is hung on one hook of rod *R*.

6. The insertion cannula of a Y-Type Recipient Set§ is pushed into S_2, and the other arm of the Y, after cutting off the dispensing cap with sterile scissors, is pushed over a glass adaptor at outlet *B* of *DB*. A hemostat is clamped on the tube near S_2 and S_2 is hung on the other hook of rod *R*.

Two more hemostats are provided for control of liquid flow in later steps.

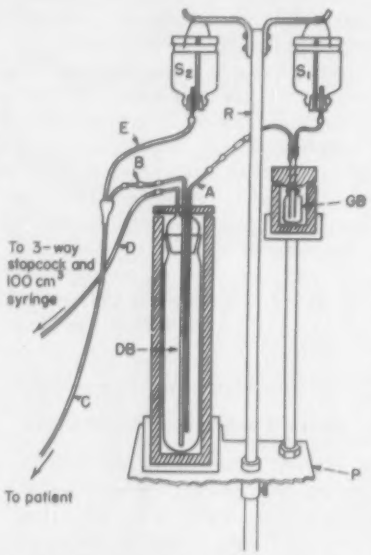
7. The 3-way metal stopcock and syringe are attached to the distal end of the rubber tube *D* on the air vent of *DB*; the stopcock is set to allow air to escape to the room when liquid rises in *DB*.

8. With hemostats properly placed and the saline bottles at highest position, saline is allowed to flow from S_1 through *GB* to *DB* until the desired volume has accumulated in *DB*. Then the tube under S_1 is clamped off. Essentially all of the gold is transferred by passage of 40–50 ml of saline. The volume in *DB* can be estimated by noting the decrease in volume in S_1, and by observing the liquid level in *DB* through the narrow vertical slits in the wall of the cylindrical lead shield. An electric bulb mounted behind one slit makes observation possible from a suitable distance.

9. Now hemostats are arranged to allow saline from S_2 to fill the delivery tube both below the Y-joint (*C*) and above this point (*B*), thus displacing all air in the syphon from *DB*. Hemostats are clamped on tubes *B* and *E*.

10. The array is elevated to the highest position on the stand and the distal end of *C* is connected to the trochar through which the patient has been tapped. Adaptors are used as required by the type of trochar employed.

11. The trochar connection is tested



INFUSION UNIT utilizes shielded shipping bottle (GB) for easy transport

ADVANTAGES OF UNIT

1. *Covered with solid cap, shielded shipment of gold can be transported to another hospital.*

2. *Two or more consecutive patients can be treated, without replacing DB, by using second gold bottle shield but same needle-hole top and same needles can be used. Venotube is attached to distal end of Y-Type Recipient Set when treating first patient; this protects against contamination of tubing above terminal Venotube by regurgitation of cavity fluid from first patient. Removal of terminal Venotube leaves tube C ready for second patient.*

3. *Technicians are well protected against radiation. On several occasions administration of radiogold to two patients in one session has produced pocket dosimeter readings no greater than 5–10 mr.*

---

* R. S. Yalow, B. B. Cohen, NUCLEONICS **11**, No. 12, 65 (1953).

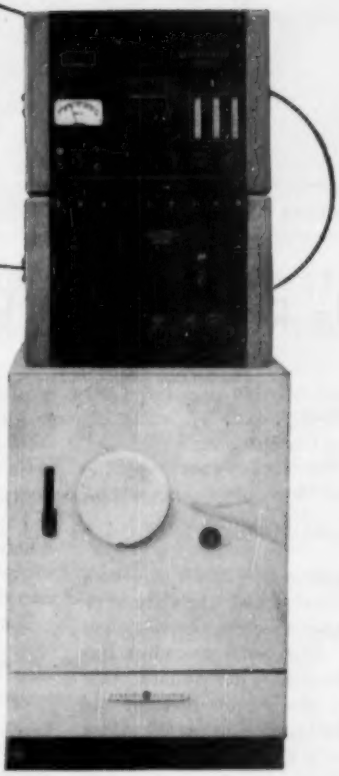
† Abbott Laboratories, Oak Ridge, Tennessee.

‡ Available from E. Machlett & Son, 220 East 23rd Street, New York 10, N. Y.

¶ Lead shields are jacketed in brass. The movable shelf, *P*, rod, *R*, (both brass) and shields are chromium plated for ease of maintenance.

§ Available from Abbott Laboratories, North Chicago, Illinois. Venotube, List No. 4429; Y-Type Recipient Set, List No. 4440. Both are plastic tubing fitted with male and female adaptors; disposable after use.

LIQUID SCINTILLATION DETECTOR



Tracerlab's unique CE-1 Liquid Scintillation Detector is designed primarily for counting samples of low energy beta emitters such as C-14 and Tritium, which can be prepared in liquid form. Efficiencies of approximately 75% for C-14 and 20 to 25% for Tritium can be obtained with this unit. The total sample volume is 50 cc and sample preparation is extremely simple.

An extremely low background of only 200 to 250 CPM is obtained by refrigeration of the phototubes, use of a dual-channel coincidence amplifier which passes only pulses which occur at the same time, and an overpulse rejection circuit. The two photomultiplier tubes with preamplifiers and a scintillation cell are mounted inside a lead shield in a small refrigerator. Samples may be stored in the dark before counting and a glove port permits transferring samples without exposure to light.

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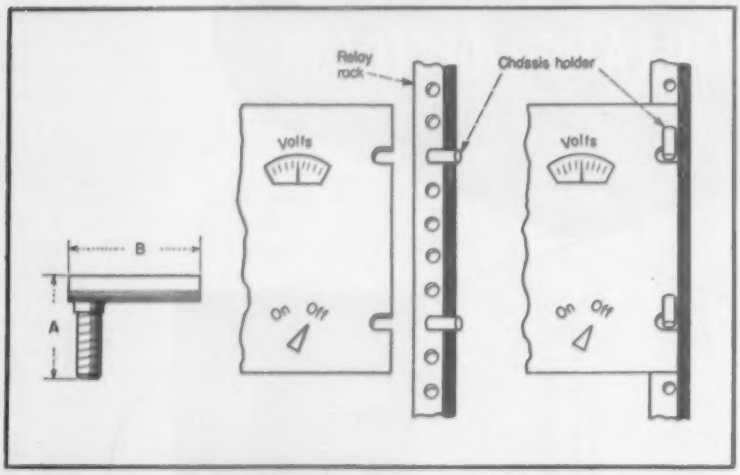
by running saline into the patient from S_2.

12. Finally, with hemostat clamped on tube E, the hemostat is removed from tube B, and the diluted radiogold colloid is syphoned into the patient. If the flow stops or slows down, gentle pressure is applied on the liquid surface in DB with the 100-ml syringe at the 3-way stopcock.

13. Hemostats are relocated, more saline is run from S_1 through GB to DB and delivered to the patient as described in **12.** If desired, tube C can be further rinsed by running a small volume of saline from S_2 through E.



CHASSIS HOLDER (left) is inserted in rack hole in horizontal position (center); chassis is slipped into place and holder turned to vertical position (right)

Simple Relay-Rack Chassis Holder

By JOSEPH GOTIMER and ALFRED WEINSTEIN
Department of Chemistry
Brookhaven National Laboratory
Upton, Long Island, New York

The chassis holder described here greatly facilitates the installation or removal of electronic chassis in a simple relay rack. The usual procedure has involved two or more individuals. One would start the screws through the front slots in the panel, while the others would support the chassis and try to align the slots with the appropriate rack holes by trial and error movements. When the circuit is removed the opposite procedure is used.

To make a chassis holder, a piece of $\frac{5}{16}$-in. brass rod, B, was hard soldered to the top of a $\frac{1}{4}$-in., $1\frac{9}{32}$ fillister-head machine screw, A. The head of the fillister screw should be machined so that it fits through the chassis's slot easily. Two or more holders may be used to mount a chassis. (B may be 1 in. long; however, where panels are recessed in the rack face, they may be shortened to allow rotation.) The holders are then inserted in the appropriate holes in the relay rack and left in the horizontal position. The chassis is then slipped into place so that the slots in the panel slide over the holders, and the panel allowed to rest on them. Where the panels had holes, slots were easily made with a hack saw by cutting into the holes from the edge.

If the holders are drawn up fairly close in advance, it is only necessary to turn them to either the up or down vertical position to hold the chassis in place. It was found that using only two holders in the bottom panel slots one person could set the chassis in position. Where heavier chassis are used and help is required, the time to set them into the rack is considerably shortened.

The chassis holders can be left in position to facilitate removing and replacing. Although four holders will hold a chassis indefinitely if they are tight enough, it is recommended that screws supplement the holders where the racks are subject to vibration.

• • •

This research was carried out under the auspices of the U. S. Atomic Energy Commission.

Preparing Samples for Absolute Counting

By S. G. RUDSTAM
The Gustaf Werner Institute for Nuclear Chemistry
University of Uppsala
Uppsala, Sweden

In the usual determination of disintegration rates, several corrections have to be applied to the observed counting rate (*1, 2*): absorption in the counter window and air, air scattering, scattering from the sample holder and counter castle, counter efficiency and geometry, sample scattering and absorption, and back-scattering from the sample support. All of these factors, except the last two, can usually be determined accurately or do not differ much from unity. By utilizing only about 0.1 mg of carrier, the effects of sample and sample support are made negligible.

Radionuclide Purification

The irradiated target is dissolved in a suitable solvent containing 0.1 mg of the element or elements to be studied. The element is then isolated and purified by a combination of chemical procedures. Since the amounts of carriers are very small, all solutions, to be as pure as possible, should be made with redistilled water. It is also preferable to purify the mineral acids and ammonia by distillation.

Extractions, distillations and scavenges are made in the usual way, but since the amount of carrier is so small, the precipitations usually have to be made in the presence of a collector substance. The collector is added to the solution and precipitated together with the element of interest either with the same or with another precipitant. The precipitate can then be centrifuged off and washed. Afterwards the collector is removed by a suitable chemical procedure. Since the precipitant must precipitate the element of interest even when the concentration is very low, many of the precipitation methods generally used in analytical chemistry are eliminated.

The final solution should be about 0.5 ml and contain the element of

interest free from all contaminants. This test solution is analyzed quantitatively, and samples for particle counting are taken from it.

Example of separation technique. Separation of copper from an arsenic target illustrates this chemical technique. The target (about 0.2 gm arsenic trioxide) is dissolved in 5 ml of 3*N* hydrochloric acid containing two drops of nitric acid and 0.1 mg Cu^{2+} as carrier. A few mg Ag^{+} are added, and gaseous hydrogen sulfide is bubbled through the solution. The solution is heated, centrifuged, and the precipitate, consisting of the sulfides of arsenic, copper and silver, is washed twice with 1*N* hydrochloric acid. The arsenic sulfide is then dissolved from the precipitate by treating it twice with 1*N* sodium hydroxide. In this step the silver sulfide serves as a collector for the small amount of copper sulfide. The precipitate is dissolved in a few drops of concentrated nitric acid, and the solution is diluted to 1*N* in nitric acid. The silver is then removed as silver chloride. The copper is precipitated with a solution of potassium ferrocyanide. About 1 mg barium chloride and a few drops of 1*N* sulfuric acid are then added to form barium sulfate, which acts as a collector for the cupric ferrocyanide. The precipitate is centrifuged and washed once with 1*N* nitric acid and twice with water. After this, the copper compound is dissolved from the precipitate in 0.5 ml dilute ammonia. In this solution, the amount of copper is determined, and samples for beta counting are taken from it. The whole procedure does not take more than about half an hour. The chemical yield, about 50%, is satisfactory. A purification step very much used with milligram quantities of copper is to precipitate copper as cuprous thiocyanate from an acid solution. However, this compound is too soluble to be used here.

The test solution has to be analyzed since the chemical yield of the actual element must be determined. Spectrophotometry is sensitive enough for the low concentration involved. Since the solution is completely free from interfering substances, it is generally possible to make spectrophotometric analyses with an accuracy of 1–2%. It is not necessary to analyze the carrier solution, since this solution can be used as a standard in the spectrophotometric analysis. One then obtains directly the ratio between the amount of the

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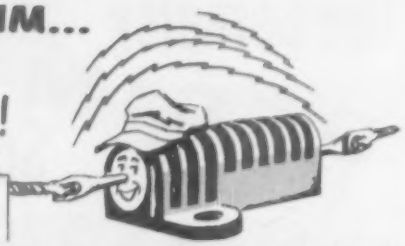

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actual element in a given volume of the test solution and the amount added as carrier. As a method of analysis of copper, spectrophotometry of copper diethyl dithiocarbamate in isoamyl alcohol at 430 mμ can be used (*3*).

Sample Mounting

The samples for particle counting are prepared in the following way. A thin aluminum foil (thickness: 0.01 mm) is stretched over a small aluminum ring (thickness: 0.5 mm; outer diameter: 25 mm; inner diameter: 18 mm) and fastened to it with small strips of tape. A small part in the center of the foil is wetted with a solution of insulin (*4*), and then 0.05 ml of the test solution is pipetted on to the wetted part of the foil with a micropipet and evaporated to dryness under a heating lamp. A fine air stream directed to the center of the under side of the foil helps to keep the liquid drop centered and to prevent boiling. By this method, good, well centered samples are obtained with a diameter of about 7.5 mm (average of 38 samples: 7.4 mm ± 0.07 mm). The effect of uneven spreading is diminished by the small diameter of the samples (*5*). The reproducibility of this method of preparing beta samples was tested by activity measurements of 38 samples prepared from a Co^{60} solution. The standard deviation of the results turned out to be 1.7%, which is satisfactory. This error includes errors in the pipetting, uneven spreading, variation of the sample diameter, etc.

Applicability of Method

The method described here has been used in an investigation not yet completed of the spallation of arsenic with high-energy protons. So far copper, zinc, nickel, and gallium have been separated and purified by this technique with satisfactory results. The technique can probably be used in almost all cases where one wants to separate spallation or fission products to determine their cross sections by particle counting.

* * *

The author wishes to thank Professor T. Svedberg for his stimulating interest in this work and Drs. A. C. Pappas and W. J. Swiatecki for helpful discussions.

BIBLIOGRAPHY

1. B. P. Burtt, NUCLEONICS **5**, No. 2, 28 (1949)
2. L. R. Zumwalt, AECU-567 (1950)
3. E. B. Sandell, "Colorimetric Determination of Traces of Metals," p. 304 (Interscience Publishers, Inc., New York, 1950)
4. L. M. Langer, *Rev. Sci. Instr.* **20**, 216 (1949)
5. G. B. Cook, J. F. Duncan, M. A. Hewitt, NUCLEONICS **5**, No. 1, 24 (1951)

Fast-Fission Cross-Sections of U^{235} and U^{238}

By NENAD RAIŠIC*
Joint Establishment for Nuclear Energy Research
Kjeller, Norway

The ratio between the fission cross-section of the uranium isotopes U^{238} and U^{235}, on the one hand, and the (n,α) cross-section of boron on the other, for neutrons of fission spectrum has been obtained by measuring the counting-rate ratio between a fission proportional counter and a BF_3 counter. The fission counter was argon filled and contained two foils on which the uranium was deposited. Natural uranium and enriched uranium deposits with a $\frac{1}{25}$ isotopic ratio were used.

The fast neutrons were produced by fission in a slug of uranium inserted deep in the thermal column of JEEP. Before entering the recording system, the neutrons were fairly well collimated. The thermal neutrons were stopped completely by a cadmium shield.

The spectrum of the neutrons in the beam did not correspond accurately with the fission-neutron spectrum because of the influence of epithermal neutrons generated by slowing-down in the collimating system. This deviation was corrected by measuring the counting-rate ratio between a lithium and the BF_3 counter. The Li_6 (n,α) cross-section is well known, both in the epithermal and fast energy regions.†

The lithium was deposited on foils similar to those used for uranium, and measured in the same counting tube, also filled with argon. This assures that the geometrical relations between fission and lithium counter, on the one hand, and the BF_3 counter, on the other, were always the same.

To determine the geometry, the counting-rate ratios were measured with 2,200-m/sec neutrons from a crystal spectrometer. The fission, lithium, and boron cross-sections for this neutron energy are fairly well known.†

The fission-boron cross-section ratios

* On leave from the Institute of Nuclear Sciences "Boris Kidric" Beograd, Yugoslavia.

† AECU-2040 (1952).

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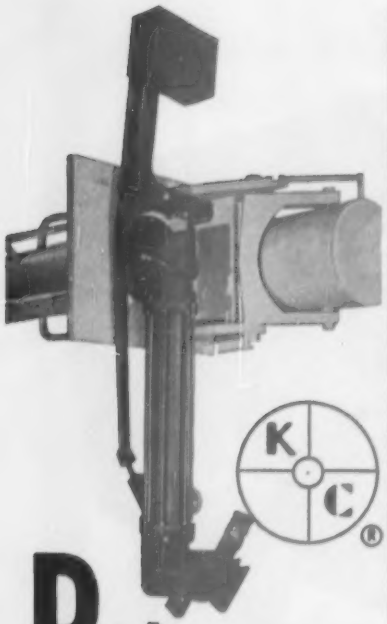

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obtained for fission-spectrum neutrons are

$$\sigma_{\text{fiss}}\,U^{235}/\sigma_B = 2.95 \pm 0.3$$
$$\sigma_{\text{fiss}}\,U^{235}/\sigma_B = 17.5 \pm 8$$

With 0.091 barn for the $B(n,\alpha)$ cross-section (integrated value over the fission-neutron spectrum), the fission cross-sections are calculated to be

$$\sigma_{\text{fiss}}\,U^{233} = 0.27 \pm 0.03 \text{ b}$$
$$\sigma_{\text{fiss}}\,U^{234} = 1.6 \pm 0.8 \text{ b}$$

The large error for U^{235} is mainly due to the uncertainty of the isotopic ratio in the enriched uranium with which the measurements were performed.

Scintillation Counter for Assay of Radon Gas

By M. A. VAN DILLA and D. H. TAYSUM
Radiobiology Laboratory
College of Medicine
University of Utah
Salt Lake City, Utah

Following the initial work of Damon and Hyde,* we have developed a simple and convenient method for assaying the exhaled air of radium-injected dogs for radon content.

The counter (Fig. 1) consists of two crystallizing dishes (30 × 50 mm) cemented together with a clear cement (R-313, Carl Biggs Co., West Los Angeles, Calif.) so as to form a 120 cm^3 closed chamber. The inner surface is coated with ZnS phosphor and the outer surface (except for the bottom) is painted white. The gas to be assayed is admitted through a packless bellows valve cemented into the top of the chamber (the valve can be replaced by a short piece of gum-rubber tubing and a pinch clamp in the interests of economy). No treatment of the exhaled breath is necessary before its introduction into the counter. The chamber is placed atop the photomultiplier and is held in place by an aluminum sleeve. No oil is used for optical coupling. It is simplest to use a photomultiplier with a flat front end. We have been using the RCA-5819 and have cemented a plano-concave Lucite disk to its front end to allow the scintillation chamber to rest on a flat surface. The scintillation pulses are fed into a pulse amplifier and scaler of conventional design.

The phosphor is applied to the inner surfaces of the two crystallizing dishes before cementing them together as follows: A thin film of silicone stopcock grease is spread over the inner surfaces of the two dishes and then wiped virtually clean. ZnS phosphor is then sprinkled on and the excess blown off. This puts a rather uniform thin layer of phosphor on the inner surface. During this process, the edges of the two dishes are protected with masking tape so that they are clean and ready for cementing.

We have made and used 20 of these counters in the past year. At the electronic operating conditions we have chosen as standard, the efficiency for radon detection is 0.75 counts per α-ray (or 2.25 counts per radon disintegration). Background is 10–20 counts/hour, of which about 1 count/hour is due to spurious pulses from the electronic gear. Hence, about 0.05

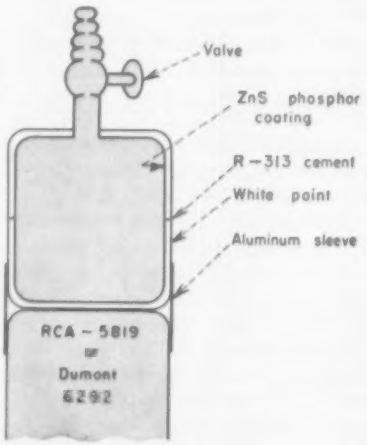

FIG. 1. Radon-assay scintillation counter

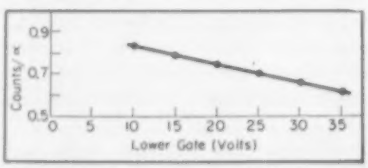

FIG. 2. Radon counting rate in scintillation as function of lower-gate setting

* P. E. Damon, H. I. Hyde, *Rev. Sci. Instr.* **23**, 776L (1952).

$\mu\mu c$ of radon in the counter will double the background counting rate.

The variation of the counting rate of a chamber containing radon gas (in nitrogen at atmospheric pressure) as a function of lower gate setting is shown in Fig. 2. We operate with a 20-volt lower gate and no upper gate. Note that the slope of this curve is 1.1% per volt; conventional electronic gear has been found to be amply stable.

The counting efficiencies of these chambers are quite uniform in spite of the fact that no special measures are taken in their construction to keep the physical factors constant (surface density of the phosphor, etc). Thus, a group of 14 counters filled with equal amounts of radon showed a standard deviation of 3.4% of the mean. Temperature effects are negligible in the range 25–40° C. The gases used for filling have been air, nitrogen, and helium. Counting efficiency for the first two are the same; helium gives a 7% advantage. Counting efficiency in nitrogen was insensitive to pressure in the range 0.5–1.0 atmosphere.

To check on possible sources of error, such as losses due to diffusion of radon into the cement or silicone grease, the decay of a quantity of radon was followed for 8.8 days. The observed half-life was 3.75 days, so that there is negligible radon loss in the materials of construction.

We have constructed similar radon counters using Lucite rather than glass. These counters have about half the background of the glass type. However, they show appreciable radon loss (presumably due to diffusion into the Lucite) over a period of several days. This loss is of the order of 1% over a period of a few hours; hence, they can be useful if it is not necessary to store radon in them for more than this time.

* * *

This research was carried out under the auspices of the U. S. Atomic Energy Commission.

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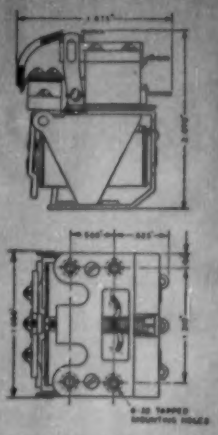

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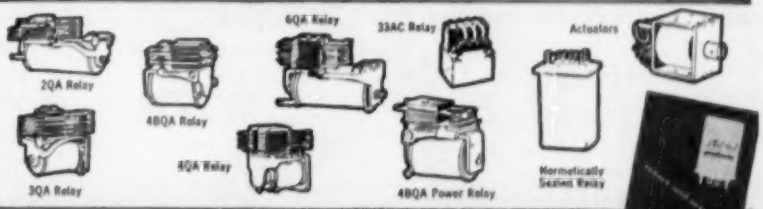

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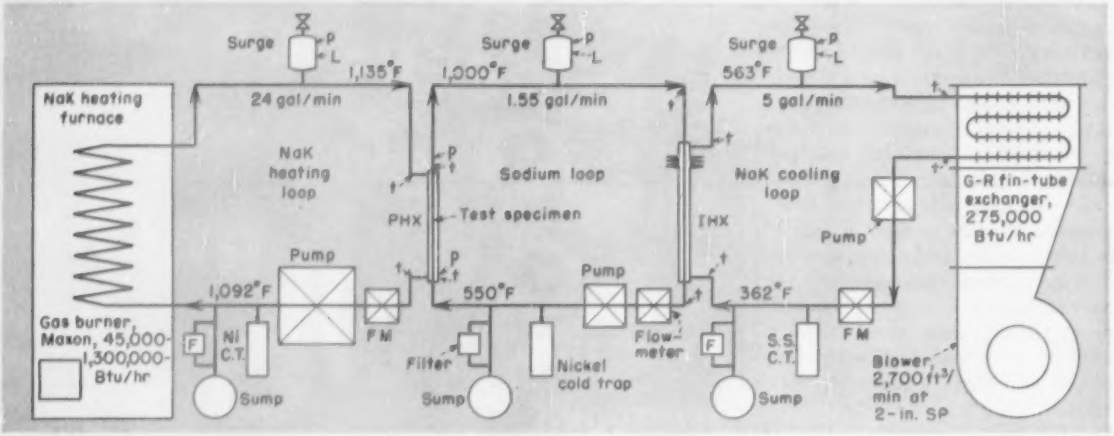

FIG. 1. Test loop used to subject cladding specimen to heat-transfer and corrosion conditions similar to those in reactor. NaK heating loop represents reactor fuel surrounding cladding tube; Na flows at high velocity inside tube. Rigid welded tube-to-sheet construction was used to keep specimen tube straight and concentric in stainless-steel shell of primary heat exchanger. Even so, differential expansion resulted in permanent set of 0.004 in./in. tube length. A bellows was not used because of the tubing's fragility and the high temperature. An MSA 220-v electromagnetic pump moved liquid metal in each loop. Cold traps kept O_2 content below 0.007 wt % in both heating NaK and Na streams. NaK heating loop was 1-in.-IPS type-316 S.S. pipe. Sodium loop used ½-in.-IPS type-347 S.S. pipe. NaK cooling loop was made of ½-in.-IPS type-304 and -316 S.S. pipe

Testing Heat Transfer and Corrosion of Globeiron for Fuel Cladding in a Na-Cooled Fast Breeder

By R. H. JONES* and R. E. LEE†

Heat transfer and corrosion tests show that Globeiron is satisfactory as a thin-walled fuel-cladding material for 30-day exposures in a sodium-cooled fast reactor.

The tests, conducted in the apparatus in Fig. 1, simulated reactor operation in which 500° F sodium enters 0.165-in.-o.d. 10-mil-wall Globeiron tubes, is heated in an average heat flux of 2×10^6 Btu/ft²/hr, and leaves at 950° F. The local heat flux, which is produced by hot NaK, varied from 1×10^6 to 3×10^6 Btu/ft²/hr over the 13½-in. exposed length of specimen.

Although test runs have been completed on tubes of Globeiron, Globeiron alloy, zirconium, and titanium, complete results are available for only the Globeiron. The tests have been intended to: (a) determine the nature and extent of sodium's attack on the tube materials, (b) determine over-all heat transfer coefficients, (c) evaluate the nature and extent of depositions or mass transfer in the Na:NaK heat exchanger and in the sodium diffusion

Globeiron Thirty-day Test Data and Calculated Results

Day of operation	*3d*	*7th*	*12th*	*21st*	*25th*	*29th*
Primary Heat Exchanger NaK-to-Na						
Temp. of NaK entering PHX,* °F	1,109	1,248	1,232	1,220	1,222	1,217
Temp. of NaK leaving PHX, °F	1,081	1,122	1,112	1,109	1,118	1,114
Temp. of Na entering PHX, °F	498	490	502	500	502	493
Temp. of Na leaving PHX, °F	948	950	952	950	952	943
Log mean temp. difference	387	444	424	416	418	424
Flow rate of Na, lb/hr	672	667	672	664	671	686
Heat transfer to Na, Btu/hr	91,400	94,000	92,600	91,400	92,400	94,400
Average heat flux, 10^6 Btu/ft²/hr	2.00	2.06	2.03	2.00	2.02	2.07
Over-all ht. tr. coeff., Btu/ft²/hr/°F	5,150	4,710	4,800	4,820	4,840	4,880
Average velocity through tube, ft/sec	30.4	30.2	30.2	30.0	30.4	31.1
Intermediate Heat Exchanger Na-to-NaK						
Temp. of NaK entering IHX,† °F	231	285	315	331	350	252
Temp. of NaK leaving IHX, °F	613	529	536	526	524	549
Log mean temp. difference	308	299	280	268	267	310
Flow rate of NaK, lb/hr	906	1,475	1,614	1,819	2,060	1,242
Heat transfer to NaK, Btu/hr	84,500	88,500	87,500	86,400	87,600	90,400
Over-all ht. tr. coeff., Btu/ft²/hr/°F	1,370	1,488	1,495	1,522	1,625	1,460

* Primary heat exchanger. † Secondary heat exchanger.

* Atomic Power Development Associates (Senior Engineer, Hartford Electric Light Co., Hartford, Conn.).

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cold trap, (d) measure the sodium pressure drop through the specimen tube under the design conditions of interest.

The Globeiron specimen, from the Globe Steel Tubes Co., was drawn by the Superior Tube Co. and had an ultimate tensile strength of 44,000 lb/in.^{2} It was composed of 99.5 + % Fe, 0.20% Mn, 0.03% C, 0.028% S, 0.02% Cu, 0.008% P, and 0.006% Si.

The loops were cleaned by the alkali metals themselves before starting each test. The loops were filled with filtered "cold" liquid metal from the sump tanks. The liquid metals were circulated around the loops as temperatures were raised to 600–700° F, where the solubilities of oxides and metals are relatively high. While still hot, the liquid metals were dumped to the sump and allowed to cool to about 300° F, where contaminants precipitated. This process was repeated several times until the liquid metals in the surge tanks were relatively clean.

Heat transfer. The table indicates that Globeiron maintained its original over-all heat-transfer coefficient throughout the 30-day period. Calculated from test data as about 4,800 Btu/ft^2/hr/° F, it correlated well with theoretical calculations using the Martinelli equation for the inside film and the Bailey equation for the shell-side film.

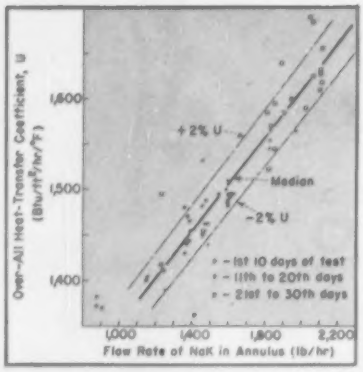

FIG. 2. Over-all heat-transfer coefficient vs annulus flow rate for intermediate heat exchanger during 30-day Globeiron test

The theories indicate that the shell-side film contributes 72% of the total resistance to heat flow while the remaining 28% resistance is divided about equally between the inside film and wall resistance. This 28% value is applicable to reactor conditions and indicates that the heat-transfer coefficient for the combined effects of the 10-mil Globeiron tube wall and the inside sodium film will be about 17,000 Btu/ft^2/hr/° F under the specified operating conditions.

Corrosion. The over-all coefficient's variation with shell-side flow rate for the Na:NaK intermediate heat exchanger is shown in Fig. 2. Most of the data falls within ±2% of the median line; this indicates that there is no fouling of the heat exchanger due to mass transfer in the sodium loop. Inspection of the tube after the 30-day run confirmed the absence of deposit.

Metallurgical examination of the Globeiron specimen tube showed no significant attack on the material due to exposure at the specified conditions; photomicrographs showed slight grain growth.

Pressure-drop data were obtained from a pressure transmitter at each end of the primary heat exchanger. Considerable trouble was experienced with this equipment during the test, so the pressure-drop data are invalid.

* * *

This article is based on a paper presented at the Reactor Heat Transfer Meeting held at Brookhaven National Laboratory, October 18 and 19, 1954.

Thermal Neutron Distribution in the Concrete Shield of JEEP

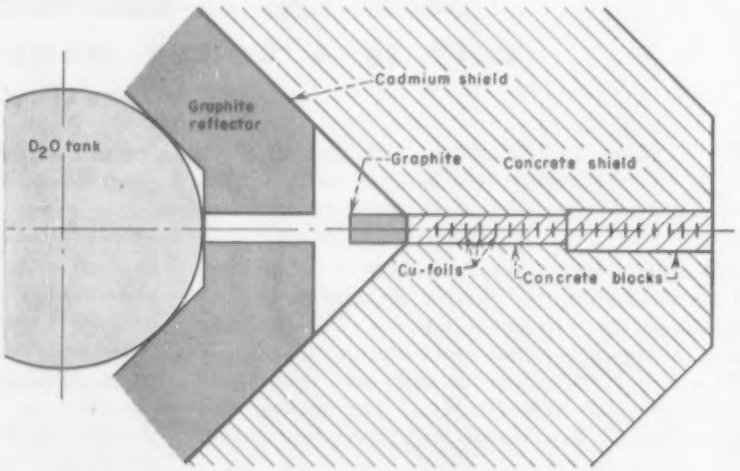

FIG. 1. Copper foils were exposed 10 cm apart in concrete blocks through shield

By F. ALDER* and H. KLEPP
Joint Establishment for Nuclear Energy Research
Kjeller, Lillestrom, Norway

Most of the absorption of thermal and fast neutrons leaving the active core of a reactor is accomplished by a thick concrete shield. In designing such a shield, it is important to know the factor by which a given neutron density decreases after penetrating a certain amount of concrete.

The theoretical treatment of this problem is very complicated because the customary age theory breaks down for large thicknesses (*1*). The simple group-diffusion method (*2*) with only two groups assumes a constant diffusion length for the fast group all over the shield. But, as the average neu-

* Member of Arbeitsgruppe Kernenergie, Switzerland. PRESENT ADDRESS: Physik Institut, Basel, Switzerland.

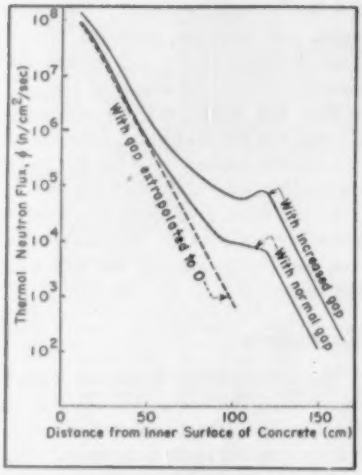
Thermal Neutron Flux, ϕ (n/cm²/sec)
With gap extrapolated to 0
With increased gap
With normal gap
Distance from Inner Surface of Concrete (cm)

FIG. 2. Neutron distribution in shield

tron energy will certainly decrease with increasing penetration thickness, the validity of this method is doubtful. Thus, an experimental determination seemed the most straightforward way.

Experimental Arrangement

Measurements were made using the JEEP reactor. Its core is surrounded by a 70-cm-thick graphite reflector and further enclosed in a 200-cm-thick concrete shield lined with cadmium sheets on the inner surface.

Figure 1 shows how two 100-cm-long concrete blocks were fitted into a channel leading through the concrete shield and the reflector to the heavy-water tank. A channel terminating at the inner surface of the concrete shield would have been more suitable, but it proved to be very difficult to introduce a graphite plug into the part of the channel that lies in the reflector. As an alternative, a 40-cm-long graphite block was attached to the inner concrete block. It was separated from the concrete block by a cadmium sheet.

The thermal-neutron flux was determined by the induced radioactivity of copper foils that had been 10 cm apart in the concrete blocks.

Measurements

All the measured flux distributions showed a very pronounced bump at the junction of the two concrete blocks. Obviously, neutrons leaked into the shield along the surface of the inner block, which did not fit very tightly. When the almost unhindered neutrons reached the outer block, they acted as an additional source. Figure 2 shows that when the gap surrounding the inner block was enlarged intentionally,

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601	30 to 400	3, 10, 30, 100
602		30, 100, 300, 1000
608		.3, 1, 3, 10 (4/hr)
613		.03, .1, .3, 1
603	400 to 2000	1500, 5000, 15000, 50000
605		0.3, 1, 3, 10
606		3, 10, 30, 100
607		30, 100, 300, 1000
604	20-50	30, 100, 300, 1000
610	I^{131} Au^{198}	1, 3, 10 mc I^{131}
609	—	3, 10, 30, 100

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the flux showed practically the same slope, but with an increased bump. Thus, it seems safe to extrapolate the measured curves to a gap of zero.

The flux could not be measured through the whole shield. After about 140 cm, the intensity was too low to be determined accurately with Cu foils.

All the fluxes given refer to a reactor power level of 250 kw. The calibration was done by comparing the flux with the central flux in the pile (*3*).

Conclusions

The neutron flux shows an almost exponential decrease. Of the simple theories, only the two-group diffusion theory predicts such a decrease. Because of the Cd-shield at the inner surface of the concrete shield, only neutrons with energy above the cadmium cut-off can enter the concrete, where they are thermalized and finally absorbed. Thus, after a sharp rise within one migration length from the cadmium shield, the thermal-neutron flux distribution follows from the two-group diffusion theory for spherical geometry

$$\phi_{th} = \phi_0 e^{-\frac{r}{M}/r}$$

where $M = L^2 + L_s^2$ = migration length in concrete, L = thermal diffusion length, L_s = slowing down length, and r = distance from center of reactor.

If the composition of the concrete and the cross sections of the contained elements for all energies were known, M could be calculated. In reactor calculations the initial neutron energy usually is assumed to be 2 Mev. The fission neutrons will be slowed down in the reflector. Using age theory, one finds that after penetrating some 70 cm of graphite, the average energy will be reduced to the cut-off energy of cadmium, so that it is reasonable to assume that the neutrons entering the concrete shield have an energy of 1 ev. For such neutrons the calculation gives $M^2 = 73$ cm². From the measurements, it follows that $M_{exp}^2 = 78$ cm², which is in good agreement with the calculation. Measurements with and without the 40-cm graphite slab showed no measurable difference in the thermal-neutron distribution in the shield.

Because $L_s > L$, an initial mixture of fast and slow neutrons entering the shield will, with increasing penetration thickness, approach a distribution only determined by the fast component. Thus, removing the cadmium shield should cause a change of the flux only at the inner part of the shield, while

the neutron flux at the outer surface of a shield of reasonable thickness remains practically unchanged. This does not mean that the cadmium shield could be omitted easily. Due to the strong penetration of gamma-rays through concrete, one should always stop the neutrons as soon as possible, so that the capture gammas must penetrate a thick layer of concrete.

BIBLIOGRAPHY

1. H. A. Bethe, AECD-2105 (1948)
2. S. Glasstone, M. C. Edlund, "The Elements of Nuclear Reactor Theory," p. 227 (D. Van Nostrand Co., Inc., New York, 1952)
3. B. Grimeland, JENER-20 (Joint Establishment for Nuclear Energy Research, Kjeller, Lillestrom, Norway, 1953)

West Germany Studies Reactor Design, Materials

While awaiting ratification of treaties to permit a 10-Mw reactor (NU, Dec. '54, p. 72), the Bonn government and West German firms are sponsoring studies of reactor design and materials technology.

The $3.5–4.75-million reactor planned for Munich or Karlsruhe is being designed at Göttingen's Max Planck Institut fur Physik by a group directed by Werner Heisenburg and Karl Wirtz. It would be similar to Britain's 6-Mw air-cooled graphite-moderated natural-U BEPO (NU, June '53, p. 68). Changes would include cutting slug spacing from 7¼ in. to 4½ in. and making cooling channels larger than BEPO's 3½ in².

In addition to research and experimental functions, the reactor would be used for producing Pu on a small scale for eventual use in an enriched power prototype. To aid Pu production, this first reactor is designed to minimize escape of resonance neutrons. Chancellor Adenauer has voluntarily pledged to restrict Pu production to 7.7 lb/yr so as to comply with the Paris agreement's clause against West German nuclear weapons production.

It is planned to use about 25 tons of domestically mined, refined, and manufactured natural-U fuel elements clad with either Al or Zr. Although the group would like to test pilot elements in a reactor flux of 10^{12} n/cm²/sec, they have been unable to make arrangements to do so. Use of D_2O has been considered to decrease fuel needs, but present plans envision using 200 tons of graphite for the moderator and an unusually large reflector.

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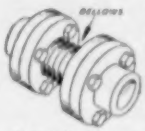

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Tritium Determines Moisture Gradient in Attached Protective Coatings

By G. D. CALKINS, M. POBEREKIN, V. E. YOUNG, and L. J. NOWACKI
Battelle Memorial Institute
Columbus, Ohio

TO DEVELOP BETTER PROTECTIVE COATINGS and alleviate the serious corrosion damage that results from their penetration, penetration mechanism must be understood (*1, 2*). Permeation of *attached* films can be studied using radioisotopes, while previously permeability data only on *unattached* films has been obtained (*3–5*). By choosing a short-range emitter (tritium) as the tracer, moisture gradient in the film can be studied. This article presents a study of moisture penetration of varnish films.

Briefly, the method consists of depositing a uniform film on a steel test disk, exposing the disk to tritiated-water vapor, and successively removing uniform film layers and determining the radioactivity of each new surface. Counting rate is convertible to film moisture concentration. "Test Technique" gives the procedure.

The procedure appears to be generally satisfactory and should be used to study penetration into all types of protective coatings on all backings of interest, under varying conditions. These data would provide a groundwork for understanding protective coating mechanisms. This initial study considered clear varnish,* as imperfections, scratches, dust and gel-particle size are easily observed in a clear film. In this varnish the range of the tritium β particle is 0.26 mil.

Experimental Results

Varnish films were exposed for 1, 10, 13, 15, 72, and 100 hours at 25° C and 100% relative humidity. Extensive penetration occurred in all cases.

Exposure for 13, 15 and 72 hours. Moisture penetration data for varnish films exposed 13, 15, and 72 hours are shown in Fig. 1. Moisture concentration, measured as tritium counting rate, was constant within a factor of 2 throughout the films. As counting conditions were modified for each test, counting rate could not be converted to water weight.

Exposure for 1 hour. Moisture completely penetrated the film during 1-hour exposures, as shown in the table. From the varnish area, the tritium activity, and the water's specific activity, the film water content was calculated. It was almost constant throughout the film thickness. These values are correct within a factor of 2 or 3; this precision probably can be improved.

Exposure for 10 and 100 hours. Before exposure these films were stored in a desiccator containing used $CaSO_4$, at an estimated relative humidity of 60%. As the films contained nonradioactive moisture, no attempt was made to convert counting rate to moisture concentration. Tritiated-water concentration decreased with increasing depth into the film as Fig. 2 shows.

Significance

The data indicated penetration throughout the film. Moisture penetration at the disk-film interface might invalidate this conclusion, for then the moisture might diffuse toward the exposed varnish surface and might also react with the steel, producing H_2 gas that might diffuse. Because only one

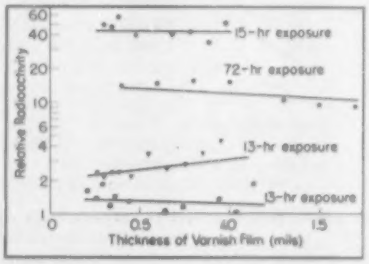


FIG. 1. Moisture gradient in varnish exposed to 100% relative humidity at 25° C for periods shown. Moisture content is proportional to radioactivity

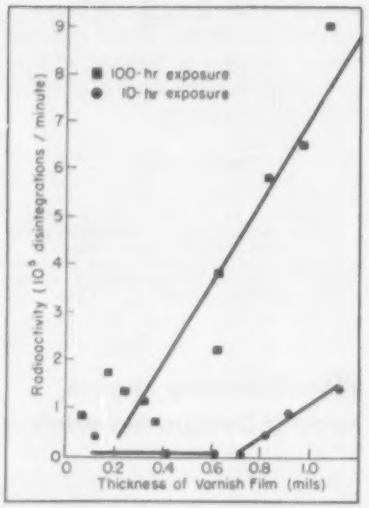


FIG. 2. Moisture gradient in varnish exposed to 60% humidity of ordinary water, then 100% humidity of tritiated water. Tritiated-moisture exposure interval shown

Moisture Penetration in Clear Varnish After 1-hr Exposure

*Varnish remaining** (*mils*)	*Radioactivity* (*10^5 disintegrations/min*)	*Moisture concentration* (*mg/cm²*)
Sample 1	Readings 2–9	0.13 ± 0.03
1.52	12†	0.65†
1.27–1.52	3	0.17
1.01–1.43	1.7	0.09
0.86–1.38	1.9	0.11
0.72–1.32	2.6	0.14
0.58–1.26	2.5	0.14
0.35–1.09	1.4	0.07
0–0.62	2.4	0.13
0–0.35	2.3	0.12
0–0.17	2.3	0.23
0	0	0
Sample 2	Readings 1–9	0.18 ± 0.03
1.28	—	—
1.03–1.28	3.8	0.20
0.87–1.28	3.8	0.21
0.72–1.24	3.2	0.17
0.58–1.18	1.6	0.09
0.44–1.12	2.9	0.16
0.31–1.05	2.3	0.13
0.18–0.98	3.9	0.22
0–0.81	3.6	0.20
0–0.63	2.6	0.24
0	0	0

* Because errors could accumulate, remaining thickness is shown as range, with total error equal to square root of sum of squares of each error.

† These values are high, probably because of surface condensation.

* Federal Specification TT-E-485-B (II), enamel for drums . . . (General Services Administration, Washington, D. C.).

experimental point (10-hr exposure) showed an increase in moisture concentration near the interface, it was concluded that interface penetration was not occurring. The 100-hr data also support this conclusion.

Hygroscopic property of varnish. The moisture concentration of about 0.15 mg/cm³ found in the films exposed for 1-hr is about six times higher than that in humidity chamber (0.023 mg/cm³). If moisture were penetrating or diffusing through pores, film moisture concentration would not exceed chamber moisture concentration. Thus, it appears that the varnish is hygroscopic to some extent.

Penetration behavior. It was hoped that 1-hr exposures would not allow moisture to permeate the varnish completely. Such specimens would have allowed initial-penetration-rate calculations. Also, any water entering at the interface could have been observed. However, the 1-hr samples showed complete and essentially uniform penetration throughout the film.

The behavior of tritiated water in the pre-exposed 10- and 100-hr samples is readily explained. Moisture content after pre-exposure at 60% humidity may have been less than would be obtained in the 100% humidity test. Upon high-humidity exposure, additional moisture would permeate and re-establish equilibrium. Based on the other results, equilibrium probably occurs in less than an hour. There was probably some exchange between normal moisture in the film and tritiated moisture in the chamber. This equilibrium occurs slowly and was not attained in the 100-hr exposure.

The pre-exposure experiments do not change the interpretation of the results, which indicate that moisture completely penetrates and attains uniform concentration in a 1.5-mil-thick varnish film in less than an hour. Data are insufficient to deduce a mechanism to explain the rapidity with which moisture permeates the varnish.

* * *

This study was performed under the sponsorship of the Department of the Army, under Contract No. DA-44-009 eng-1732.

BIBLIOGRAPHY

1. J. K. Wirth, W. Machu, *Paint, Oil, Chem. Rev.* **117,** No. 5, 26 (1954)
2. A. C. Elm, *Offic. Dig. Federation Paint & Varnish Prod. Clubs* **No. 264–275,** 197 (1947)
3. W. K. Asbeck, M. Van Loo, *Ind. Eng. Chem.* **41,** 1470 (1949)
4. I. Wolock, B. L. Harris, *Ind. Eng. Chem.* **42,** 1347 (1950)
5. S. Eckhaus, I. Wolock, B. L. Harris, *Ind. Eng. Chem.* **45,** 426 (1953)
6. M. Calvin, *et. al.*, "Isotopic Carbon," (John Wiley & Sons, Inc., New York, 1949)

Test Technique

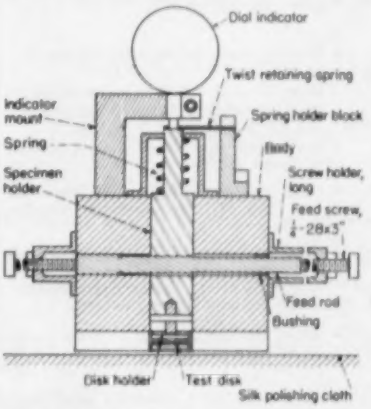
1. Preparing test disks. *Disks 1-in. diameter × ¼-in. thick are carefully machined from cold-rolled steel, the surface polished to a smooth, not mirror, finish, and degreased with toluene. Disk is cemented with Duco to disk holder, of same dimensions. Micrometer measurements after cementing insure front and back face parallelism within 0.2 mil. Disks are placed in well-type holder and varnish applied with dropper. Doctor blade drawn over disk leaves uniform film about 1.5-mils thick, as calculated from film weight, disk surface and varnish density. Air drying for 1 hr prevents film from shrinking at edge. Baking at 300° F for 20 min cures varnish.*

2. Exposing varnish. *Test disks are suspended by Pt wire so varnished face is parallel to and above tritiated water in glass planchet. Assembly is enclosed in sealed 8-oz wide mouth bottle placed in water bath kept at 25 ± 0.5° C. Relative humidity of 100% is maintained. Water activity is 5.50 ± 1.10 × 10⁵ dpm/mg. Unvarnished parts of disk are covered by electroplating tape to reduce corrosion during exposure.*

3. Polishing preparation. *Tape is stripped when disk is removed after exposure and disk is put in covered weighing bottle. Assembly is quickly cooled to −20° C, or lower and kept there during remaining operations to minimize evaporation (water's vapor pressure is 0.776 mm Hg at this temperature). Low temperature also increases varnish hardness, facilitating polishing. Remasking before polishing (by brushing on 10% collodion and letting it air dry), eliminates possibility of measuring radiation from surfaces other than the varnish, and minimizes detector contamination. After remasking disk is placed in polishing jig.*

4. Polishing. *Specially designed polishing jig holds test disk as uniform 0.1-mil-varnish layers are removed. After removing each layer, disk is counted to determine tritium content of varnish, but before counting starts about 0.2 mils of varnish are removed to minimize detector contamination and to secure a plane surface for future operations.*

Polishing jig (at right) has carefully machined surfaces that keep varnish surface horizontal. First step in removing varnish layer is attaching disk holder to specimen holder with a taper pin. Disk is lowered by adjusting feed screw so that desired film thickness protrudes beyond jig's bottom. Sliding jig over silk polishing cloth mounted on stationary metallographic polishing wheel removes protruding layer. Silk is only material tested that removes varnish without scratching it. New cloth area is used for each stroke to avoid contamination.



Constant-reading micrometer (0.1-mil divisions) indicates film thickness removed. Following film removal disk holder is taken off and film thickness determined at four points by micrometer calipers to check that a plane parallel section has been removed. Tests with 0.0001-in. caliper show that thickness can be measured to 0.1 ± 0.15 mil. After thickness measurement sample is counted.

5. Counting. *Proportional-flow counter using methane gas (>99% purity) and scaler are used for counting. In counting arrangement, counting gas passes through Tygon tubing coiled in dry ice and thus is kept at −35 ± 10° C.*

At temperatures below 0° C sample counting rate decreases with decreasing temperature. At temperature used, correction factor for this effect is 1.5. Other correction factors, to convert counting rate to disintegrations per minute, are 10 for geometry, based on experiments, and 5 for self-absorption, based on calculations for an "infinitely thick"—0.26 mil—varnish layer (6). Thus, over-all correction factor is 75. Because last layer of varnish is less than 0.26 mil thick, self-absorption is reduced. Assuming a thickness of 0.2 mil, factor is 4; making over-all correction factor 60.

No correction for backscattering from steel disk is needed, as scattered particles will not penetrate 0.26 mil of varnish. For a 0.2 mil thickness, less than 3% of activity results from backscattering.

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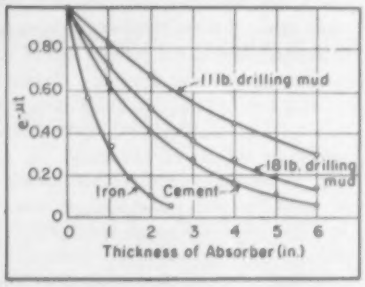

FIG. 1. Radiation-absorption factors

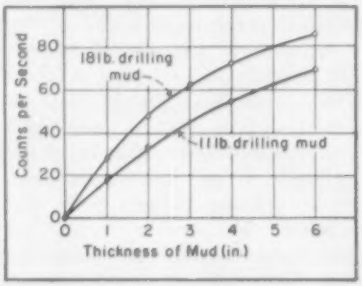

FIG. 2. Drilling-mud radioactivity

Borehole Radioactivity

In U. S. 2,686,881 (assigned to The Texas Co.), Gerhard Herzog and Alexander S. McKay describe a method for determining the absolute radioactivity of boreholes for interpreting the geological formations at various depths.

To determine the absolute radioactivity, corrections must be made for absorption of γ-rays by the well casing, cement around the casing, and the drilling mud and for γ-rays normally emitted by the drilling mud. Typical dimensions of these materials in a borehole are: cement, 1 in. thick; steel casing, ¼ in. thick; drilling mud, 2 in.; and the counting instrument is suspended in a 3⅝-in. cavity. These corrections are expressed as

$$I = I_0(e^{-\mu_1 t_1} \times e^{-\mu_2 t_2} \times e^{-\mu_3 t_3}) + f(DMt)$$

where I is the observed counting rate, I_0 is the rate that would be observed in a dry uncased hole ("absolute" activity), the bracketed terms are the absorptions (taken from Fig. 2), and $f(DMt)$ is the radioactivity of the drilling mud (taken from Fig. 3). The radioactivity of the mud is determined by dipping the counter in a known thickness of mud outside the borehole.

Radioactive-Gas Emanator

In the conventional method of generating radon, oxygen passed through a radium bromide solution carries out the accumulated radon gas. Elaborate filtration is necessary to prevent droplets of the radium solution from passing through the gas outlet. The method described in U. S. 2,688,098, issued to Augusto A. Monasterio, avoids this disadvantage by using no liquid solution.

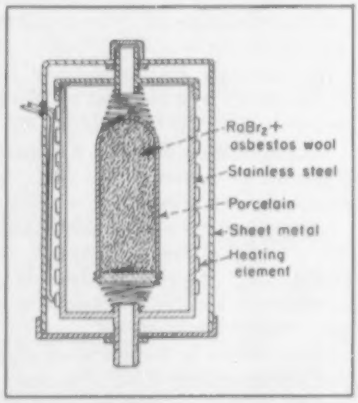

FIG. 3. Radioactive-gas emanator

As shown in Fig. 3, a closed porous porcelain capsule is filled with a carrier, e.g., asbestos wool, which has been impregnated with radium bromide solution and dessicated. The capsule walls, impervious to radium particles, are shock-proof mounted between springs. The bottom nipple is connected through a valve to a radon-gas storage container, which is filled by vacuum. The cap on top permits flushing out the capsule. The heating element maintains a temperature of 500° F to accelerate emanation.

NO-Quenched Counter

Herbert Friedman discloses an improvement in self-quenched G-M tubes in U. S. 2,688,097. By using a quenching mixture of 0.5–5.0% nitric oxide in a rare gas such as neon, the useful life of the tube is increased from 10^8 to 10^{10} counts. In addition, the regenerative powers of the mixture permit repeated use of the tube after suitable storage periods; this is apparently due to recomposition of the quenching constituent, which may have been decomposed in the act of quenching. The NO freezing point is low enough so that

tube can be operated successfully in liquid air.

Radiation Detectors

The Polaroid Corp. has recently taken out three patents on radiation detection devices.

U. S. 2,687,478, by Edwin H. Land, describes a film unit for detecting nuclear radiation, which can be held and processed in the mouth of the user.

U. S. 2,689,307, by Murray N. Fairbank, describes a dosimeter in which an envelope contains a photosensitive element as well as a rupturable container of a photographic processing composition.

U. S. 2,689,308, by Edwin H. Land, describes a dosimeter containing an alkali halide crystal that becomes blue when subjected to X- or γ-radiation. The device for measuring the color change consists of a red filter, a split-field polarizer, and a rotatable analyzer.

* * *

These descriptions are based on abstracts furnished by Melvin Nord, Registered Professional Engineer, Patent Attorney, Detroit, Mich.

*Government-Owned Patents**

Uranium-Nickel Metal Alloy (2,692,823), M. E. Cieslicki, B. J. Nelson—Binary uranium-nickel alloy (U_6Ni), useful in construction of nuclear reactors, has improved corrosion resistance through incorporation of nickel.

Liquid Sampler (2,693,705), J. A. Casler, H. O. Smith, L. F. Coleman, M. Levenson—Sampling apparatus for radioactive corrosive or valuable liquids; sample is removed from source container by aspirator into sampling container, then into aspirator stream back into source container. Natural agitation assures representative sample.

Radio Electric Generator (2,696,564), P. E. Ohmart—In converting radioactivity to electrical energy, radiation detector requiring no external electrical source generates current proportional to amount of radiation.

The Isotope of Curium Having a Mass Number of 238 (2,698,290), G. T. Seaborg, K. Street, Jr.—Describes production of Cm^{238} by 80-Mev-alpha bombardment of Pu^{239} with cyclotron and chemical separation of isotope from resulting mixture; Cm^{238} is identified by alpha-particle pulse analysis.

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BOOKS

Radiation Biology, Vol. 1: High Energy Radiation (Parts 1 and 2)

ALEXANDER HOLLAENDER, editor (McGraw-Hill Book Co., Inc., New York, 1954, ix + 1265 pages, $17.50 for both parts). Reviewed by A. J. CIPRIANI, Atomic Energy of Canada Ltd., Chalk River, Ontario, Canada.

This book is contained in two volumes and eighteen chapters, each written by an expert in the field. The work is sufficiently elementary in part to be understood by beginners. On the other hand, there is enough advanced material to make it useful to the experienced radiobiologist.

The first chapter deals with the physical interaction of radiation with matter. Although it is principally concerned with high-energy radiation, the treatment is such as to apply to electromagnetic radiation in general.

The second chapter explains the all-important subject of dosimetry. It discusses the pitfalls likely to beset the experimenter and makes suggestions for avoiding them.

The third chapter is concerned with the physical-chemical reactions that follow the absorption of electromagnetic energy. It is nonmathematical.

Chapter four explains the primary chemical reactions that follow the introduction of energy into a biological system. It starts with the radiation chemistry of water and describes the reactions of biological interest that can be reproduced *in vitro*.

Chapter five goes on to describe the reactions of interest *in vivo*.

Chapter six deals with linear energy transfer or what might be termed microdosimetry. It points out that the reaction under consideration and the material being irradiated are additional factors of importance. There are sufficient examples given of relative biological effectiveness of different radiations to emphasize the state of confusion in this field.

Chapter seven deals extensively with the genetic effects of radiation. The opening remarks of this chapter may well be the most controversial in the book.

Chapter eight outlines the present ideas of the mechanism of production of mutations. Since mutations are largely considered to be the most undesirable effect of radiation, it is an important discourse.

Chapters nine and ten are concerned with chromosome aberrations in plants and animals. They are largely descriptive of the changes that are found and go on to describe the mechanism of their production with some reference to their implications in the life of the cell.

Chapter eleven describes the immediate effect of radiation on subsequent cell division. It is also concerned with the extraneous factors that might influence post-irradiation mitosis. The immediate observable effects on the chromosomes are given together with their significance in cell viability.

Chapter twelve discusses the genetic experiments from which conclusions regarding the genetic effects of radiation on the human race might well be drawn. These experiments largely on the mouse are still in progress so that information on this subject is incomplete.

Chapter thirteen covers radiation in prenatal development. This is an important subject in the field of radiation protection, but strangely enough its investigation has placed an important tool in the hands of the embryologist.

Chapter fourteen is somewhat of a recapitulation of earlier chapters. It also deals with the important question of radiation sensitivity and radiation resistance.

Chapter fifteen deals with the physiology of radiation injury after it becomes apparent in the whole organism. It outlines in a very useful manner the present concept of the steps leading to acute radiation injury.

Chapter sixteen is on the haematological effects of radiation. There is probably no subject in this field on which more data has been accumulated. The scope of this chapter is very broad and one must rely on the references for detail.

Chapter seventeen describes the histological effects of radiation on the different mammalian tissues and again discusses the question of radiosensitivity.

Chapter eighteen deals with radiation carcinogenesis by referring to the effects of different forms of radiation and the susceptibility of different organs to tumor growth. The probable mechanisms of cancer production are discussed.

From the above description can be seen the wide range of subject matter covered. This and the numerous references given at the end of each chapter

make this the most useful work of its kind in the field of radiobiology. Its one weakness is the repetition which is inherent in a book compiled from the work of so many authors. Its treatment of the clinical effects of radiation is incomplete, but there is enough material to make it useful to the radiation therapist and any one interested in the use of radioactive isotopes.

That most of the material dates back to 1951 does not detract from the usefulness of the work since there have been really no major advances in the field since then. Rather, it is evidence of the considerable effort that must have been expended in its production.

Physical Aspects of Betatron Therapy

By JOHN S. LAUGHLIN (Charles C Thomas, Springfield, 1954, xiv + 98 pages, $3.75). Reviewed by H. E. JOHNS, Saskatchewan Cancer Commission, Saskatoon, Saskatchewan, Canada.

This well written monograph will be found useful to those using or contemplating the use of high-energy X-rays and electron beams in radiotherapy. The book will also be useful to radiation physicists interested in the interaction of high-energy radiation with matter. The author is well qualified to write such a book since he is one of the few men who have had practical experience with the betatron in the treatment of cancer. The book is written in two sections. The first section deals with high-energy X-rays and the second section with high-energy electrons.

The first two chapters discuss briefly the methods of producing high-energy X-rays with the betatron. The spectral and spacial distributions of this radiation are discussed. The results of depth-dose measurements are presented and the preferential absorption in bone and other biological materials discussed. The practical value of the book would be increased with the addition of a number of isodose curves.

Chapters three and four are concerned with measurements of the radiation level at various points around the machine and in the control room. It is to be noted that since this book was written, further advances in the design of medical betatrons have taken place.

Chapter five is concerned with a few of the clinical applications in both fixed-field and rotation therapy.

There follows a chapter on dosimetry in which the original work of Dr. Laughlin with the calorimeter is capably dis-

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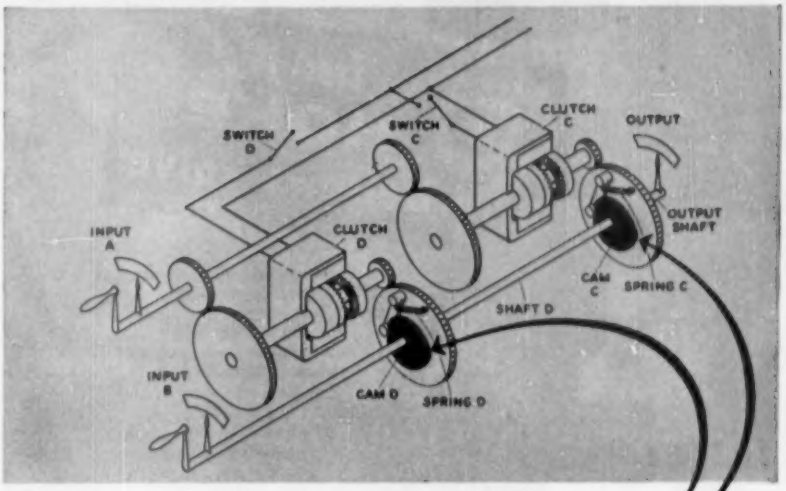

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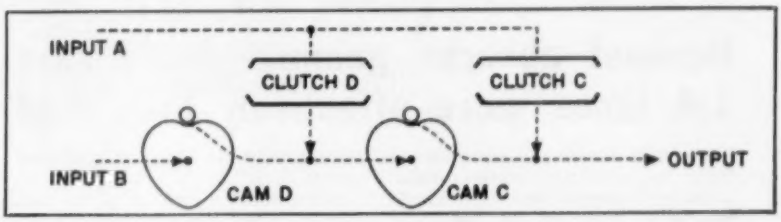

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cussed. The first section of the book concludes with a summary of the relative biological efficiencies of 20-Mev X-rays as compared with conventional radiation.

The second section of the book deals with electron-beam therapy, concerning which Dr. Laughlin is highly qualified to write. Almost all the high-energy electron therapy to the present time has been carried out by him. The book ably discusses ionization distributions and dosimetry for electrons.

The monograph concludes with brief discussions of the clinical applications and the biological effectiveness of high-energy electrons.

Physical Properties of Solid Materials

By C. ZWIKKER (Interscience Publishers, Inc., New York, 1954, viii + 300 pages, $8.75), Reviewed by D. S. BILLINGTON, Solid State Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.

This book, in the words of the author, is an effort to provide, in a single volume, a summary of the physics of solids. The author's motive is highly commendable, as a book providing a comprehensive coverage of the field of solid state physics is much in demand. Activity in this field has been accelerating since World War 2, with many important scientific and technical advances having been made. There are many new workers in the field and there is an increasing awareness in academic, military, and industrial fields of the importance of solid state studies.

It would be a pleasure to be able to say that the author has succeeded in meeting the demand for a modern bible of the solid state, but unfortunately the book tried to cover too much territory in too few pages. In 300 pages, including indices, not only are conventional solid-state physics topics treated but, in addition, many other topics, normally not included in a book of this sort. For example, pigments, paints, the mechanical strength of stones and asphalt and other topics as well as Chapter 14, *The Surface*.

The brevity of the text means that the treatment of nearly all topics is of insufficient detail. It would have been interesting to see the present work expanded to 600–900 pages.

There is observed in this book, and others of a similar nature published since 1945, a tendency to write shorter and shorter books with less and less

detail on more and more topics. This is to be deplored.

In spite of the concern over the brief treatment, I must say that I enjoyed reading the book. The text is presented in an interesting, easily read fashion. Numerous fine tables, graphs, and photographs supplement the text. Though the treatment is meant to be theoretical, there are often included novel practical examples that are thought provoking. The literature cited is extensive and includes references through 1951.

It should be emphasized that the book is not meant to be an elementary textbook, since a generous background in chemistry and physics is a necessary prerequisite to adequate understanding.

The subject matter is covered in 14 chapters as follows: *Elementary Particles and Forces; Constitution; Heterogeneity; Anisotropy; Systematic Relations; Elasticity; Elastic After-Effect and Damping, Dielectric Losses; Plasticity; Thermal Properties; Transformations; Porosity and Permeability; Ferromagnetism and Ferroelectricity; Electronic Properties; The Surface.*

The chapter titles suggest that the arrangement of material is unconventional, and a closer inspection of topics covered confirms this thought. The arrangement, while novel, does not detract from the value of the book. In fact this may be one of its strongest points, as the reader is led to regard many subjects in a different light than he is normally accustomed to understand them.

For example, the plastic deformation of metals is examined in the chapter on anisotropy and again in the chapter on plasticity, while background for both of these chapters is treated under elasticity, with additional material in elastic after-effects and damping. The point is that the plastic deformation of metals is considered just another example in the general field of anisotropy and not the reverse as is conventional.

One other novel feature is the use of the meter-kilogram-second-ampere-centigrade system of units throughout the book. The choice is dictated by the desirability of employing an international set of units. One must subscribe to this motive, but it is unlikely that the use of Newtons per square meter when dealing with pressures will ever become popular.

The usual allotment of errors is included in this book, typographical and otherwise. Typical are the following:

On p. 76—the derivation of the gen-

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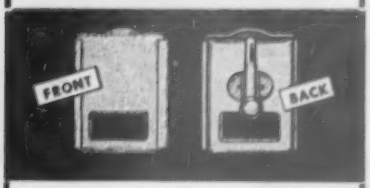

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eral relation $K_{LL} - 1/k_{LL} = K^2_{kL}/K_{kk}$ seems obscure.

On p. 129—Fig. 8.7 does not appear to be drawn correctly.

On p. 130—it is doubtful if it is now accepted that dislocations move at the velocity of sound.

On p. 172—grey tin is the alpha form not beta.

On p. 179—the transition temperature of Cu_3Au is given as 110° C instead of 386° C.

The chapters on *Anisotropy* and *Electronic Properties* were well done. As were most of the other chapters, if one makes allowance for space allotted.

It is believed that most workers in the solid state field will have something of value to gain from this book and should find reference to it useful in their research.

ALSO OF NOTE

Some Biological Effects of Radiation from Nuclear Detonations. This booklet, reprinted from *The American Naturalist* (July–Aug., 1954, p. 209), is the report of a symposium held at the Joint Session of the American Society of Naturalists and the Genetics Society of America at the meeting of the American Association for Advancement of Science, Boston, Massachusetts, Dec. 28, 1953. *Science Press, Lancaster, Pa.*

The New Atomic Energy Law—What It Means to Industry. This report of a meeting in New York, Sept. 27–28, sponsored by the Atomic Industrial Forum, presents the views of authorities from government and industry. Included are sections on interpretation of the 1954 Act, investment problems and opportunities, future outlook, industry-government relations, government implementation of the law, labor outlook, and insurance problems. *Atomic Industrial Forum, Inc., 260 Madison Ave., New York 16, N. Y., $5.00.*

Legal Control of Thermonuclear Energy—The Atomic Energy Act and the Hydrogen Program. This 38-page article by John S. Walker is reprinted from the June '54 "Michigan Law Review." Including many references to comments of legal and scientific experts and the Atomic Energy Act of 1946, Walker develops the point that military and peacetime applications of thermonuclear energy have not received proper encouragement and priority. *Michigan Law Review Association, Ann Arbor, Mich.*

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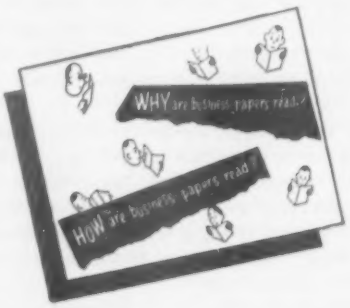

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NEWSMAKERS

Lauriston S. Taylor of the National Bureau of Standards has been presented the Gold Medal of the Radiological Society of North America for leadership in radiation protection.

Edward R. Trapnell, special assistant for Congressional relations to the AEC general manager, has resigned. He is joining the New York advertising and public relations firm of Bozell & Jacobs, Inc.

Alvin Radkowsky has received the Navy's distinguished civilian service award for his work on nuclear power projects while with Bureau of Ships. He's now with AEC's naval reactors branch.

John Christian Warner, president of Carnegie Institute of Technology, has been named president-elect of the American Chemical Society. He'll head the society in 1956.

William O. Faxon has been named a director and executive vice president of Tracerlab, Inc.

Samuel M. Seidlin, endocrinologist and pioneer in the use of radioiodine in thyroid diseases, died in January. He was 59.

Russell Field, formerly with AEC in Oak Ridge, has joined the engineering and construction firm of Holmes & Narver, Inc., as a project engineer.

Robert D. Nininger has replaced **Phillip L. Merritt** as assistant director for exploration in AEC's division of raw materials. Merritt resigned to join E. J. Longyear & Co. as senior geologist. He will have offices in New York.

F. Seymour Henck, assistant for public education to the manager of AEC's Oak Ridge Operations Office, has resigned to join Campbell-Mithun, Inc., Minneapolis and Chicago advertising agency. **Edwin E. Stokely** replaces him, with **Wayne Range,** former public information officer for AEC's Portsmouth area, assuming Stokely's public information post at Oak Ridge.

L. R. Hafstad, former director of reactor development for AEC, has been awarded the AEC distinguished service award. Hafstad is now with Chase National Bank of New York.

Ralph D. Bennett has resigned as technical director of Naval Ordnance Laboratory to assume the same position at Knolls Atomic Power Laboratory.

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Firm name and address	*Cost of service (per badge)*	*Minimum*		*How often are badges supplied*	*Control badge provided*	*Time to report exposures*	*Interval badge is kept on file*	*Finger or hand badges*	*Related services*
		No. of badges	*Subscript. period*						
Atomic Research Lab., 2633 Santa Monica Blvd., Santa Monica, Cal.	$1-1, 80¢-2, 65¢-3–10, 60¢-11–25	None	None	Weekly, bi-weekly, or monthly	Yes	7 days	Permanently	$1.50 apiece, then film prices	Consulting, monitoring, surveys
Isotopes Specialties Co., 3816 San Fernando Rd., Glendale, Calif.	50¢ apiece (quantity discounts allowed)	13	None	Weekly	Yes	Within 7 days	6 years	Wrist bracelet sold, then 50¢ per film	None
R. S. Landauer, Jr. and Co., P. O. Box 102, Park Forest, Ill.	$1.20-1, 50¢ each add. Over 50-quantity prices	None	13 weeks (shorter at higher price)	Weekly, bi-weekly, or special arrangement	Yes	About 2 days*	Permanently	Same price as badges	Area monitoring badges 5-$12, $1.25-add.
Nuclear Consultants, Inc., 33-61 Crescent St., Long Island City 6, N. Y.	$1-1, 60¢-2–9, 50¢-10 and over	1	3 months	Twice a month	No	7 days	2 years	None	Consulting
Nuclear Inst. and Chemical Corp., 223 W. Erie St., Chicago 10, Ill.	65¢-3–24, 60¢-25–49, 55¢-50–99, 50¢->100†	None	None	Weekly, bi-weekly, or monthly	Yes (3 or more badges)	4 days*	Permanently	None	ORNL packets-55¢-40¢ ea., consulting
Radiation Detection Co., 576 College Ave., Palo Alto, Calif.	50¢ (weekly) 60¢ (bi-wk.) $10 per yr (monthly)	None	26 wk if 1-2, 13 wk if >3	Weekly, bi-weekly, or monthly	Yes	Within 2 days*	Permanently	70¢ apiece	Badge storage racks, consulting
R-C Scientific Inst. Co., 307 Culver Blvd., Playa del Rey, Calif.	60¢ apiece $2.50 min. quantity discounts	None	13 periods	Weekly or longer scheduled period	Yes	Within 7 days	Indefinite	Finger ring-75¢ ($3 min.)	Survey pack of 10-$10
St. John X-Ray Lab., Califon, New Jersey	50¢ per badge $75/yr min.	None	1 year	As desired or user holds supply	Yes	Within a few days	Badge is returned to user	None	Environment monitoring
Technical Associates, 140 W. Providencia Ave., Burbank, Calif.	60¢; less on quant. or yr contracts	3	13 periods	Weekly, bi-weekly, or special arrangement	Yes	Within 7 days	Indefinitely	Wrist bands-$1, then 60¢ per film	Consultation
Technical Operations, Inc., 6 Schouler Ct., Arlington, Mass.	75¢ each (discounts on contracts)	None	None	As ordered (3 mo. max. storage)	Yes (sold)	3 days	Indefinite	None	None
Tracerlab, Inc., 130 High St., Boston 10, Mass.‡	60¢ apiece, over 25-quantity discounts	3	13 weeks	Weekly or any regular schedule	Yes	Within 5 days*	Permanently	Wrist band-$1.50, then film prices	Consulting; body survey packet

* Will notify of any overexposures by collect telegram, if requested. † Deduct 5% for yearly contract on weekly basis. Price Richmond 2, Calif.

materials of particular use in atomic-energy work will be reported.

Film-badge dosimetry is complicated by the energy spectrum encountered, and by whether mixed β and γ is present, plus the variables of film sensitivity, processing conditions, and radiation discrimination method. Because of this, the accuracy tabulated is a typical figure and does not represent either the best obtainable or a guaranteed performance. If radiation energy is known, better accuracy is possible.

Tabulated data do not include neutron badges or film-badge holders for sale. These data follow.

Neutron Badges

Radiation Detection Co. and Tracerlab, Inc. supply neutron badges at $1.25 each. Both firms use Po-Be sources for calibration. Tracerlab claims recordable energy range of up to 20 Mev; an uncertain film dose range, as γ background affects range; and an accuracy in line with that obtained by the AEC. Radiation Detection claims thermal and high-energy neutrons are recordable; a dose range of 20% of tolerance to an indefinite upper limit; and an accuracy for tolerance flux no better than 100%, but better accuracy as exposure increases.

R. S. Landauer reports it is inaugurating neutron-badge service in February, at about $1.20. Atomic

Method of distinguishing X-, γ, and β rays	*How often calib. film processed*	*Gamma rays*				*Beta rays*			
		Calibration source	*Accuracy (%)*	*Energy range recordable*	*Film dose range*	*Calibration source*	*Accuracy (%)*	*Energy range recordable*	*Film dose range*
Copper step wedge	Monthly	Radium, X-ray (Co^{60} optional)	10	50 kv–250 kv X-ray (min.)	10 mr–10 r	Sr^{90}	25	100 kev–3 Mev	10 mr–10 r
Step wedge	With each batch	Co^{60}	10% or 15 mr high energy gammas	30 kev–>5 Mev	10 mr–500 r	Sr^{90}-Y^{90} 1-mil. s. s., 50-cm air filtering	50	10 kev–>3 Mev	10 mr–>500 r
Open window; 4 different absorbers	With each customer batch	Film exposed at energy found from darkening ratios	20	30 kev–about 5 Mev (at stated accuracy)	30 mr–600 r (×0.1 for low energy γ)	Use β emitter specified by customer	About 20	400 kev–higher	60 mrep–1200 rep (higher for lower energy)
Open window; 0.5-mm Cu, 1-mm Cd filters	With each batch	X-ray, Co^{60}	20 (>140 kv)	40 kv and up	50 mr–20 r	Not calibrated for beta.			
Open window; 10-mil Cu, 40-mil Cd, 40-mil Al	With each batch	X-ray, Co^{60}	20	25 kev–10 Mev	50 mr–500 r	Subtract background from open window reading to get equivalent exposure caused by β rays. Possible factor of 2.5 unless β energy known.			
Open window; Al, Cd, 27-mil Pb filters	With each batch	30 kev X-rays, Co^{60}	20	25 kev–3 Mev, special calib. for others	30 mr–400 r (–50 r low energy γ)	Film sensitivity calibrated	25% if energy known, no low γ	1 Mev–higher	50 mrep–400 rep
Open window; 20-mil Ag, 21-mil Pb filters	With each batch	X-ray, Co^{60}; special sources on request	20	30 kv and up	10 mr–750 r (3 films)	U^{233} or other on request	20	1 Mev and up	10 mrem–>1,000 rem
γ given, factors to convert to X-ray	With each batch	Co^{60}	20	Dupont 552 film figures		Do not monitor, but for rough estimate of β, multiply our figure by 3.			
2 Cu, 2 Al, 1 Cd filter	With each batch	45-, 100-, 200-kvp X-rays, Co^{60}	25	45 kvp–1.3 Mev	25 mr–100 r	U^{233}, and emitter specification	Dosage estimate based on U β curve	400 kev–higher	100 mr–50 r
Filters	With each customer batch	50–250-kv X-rays, Co^{60}	10–25%	50 kv–2,000 kv	25 mr–20 r	Not calibrated for beta.			
Cu step wedge; or Cd filter, open window	With each batch	X-ray, Co^{60}	Dependent upon status of source knowledge	10 kev and up	20 mr–50 r (–2,000 r on request	U^{233}, and emitter specification	In line with AEC install. performance	150 kev–higher	30 mrep–80 rep

for 1 badge-$1, for 2-87.5¢. ‡For the 17 western states; Tracerlab, Inc., Western Division Film Badge Service, 759 23rd St.,

Research Co. reports a neutron-film-badge service is in development.

Film Holders for Sale

A. M. Samples Machine Co.* offers 10 models of badge holders at $1.25–1.75 apiece (quantity discounts). They hold two dental sized film packets, and have two Cd shields. Holders weigh about 1-oz, various attachment means are available. One holder is on a wrist bracelet.

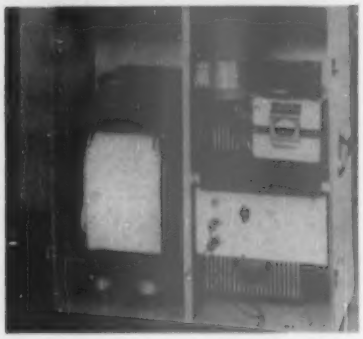
The following firms offer to sell their complete film badge as described in the table but without service: Nuclear Inst. & Chem., $1.25; R-C Scientific Inst., $1.50; St. John (ORNL type), $1.50; and Technical Operations, $0.75.

* * *

Copies of this survey, at 10 cents each, can be obtained from Reprint Department, NUCLEONICS, 330 West 42nd Street, New York 36, N. Y.

The Editors of NUCLEONICS wish to thank Hanson Blatz of the AEC New York Operations Office for his assistance and advice in preparing this survey.

RADIATION DETECTORS AND ACCESSORIES



Portable Recording Monitor

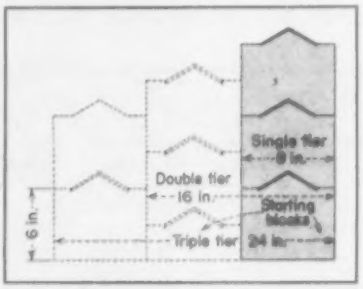
Model PRAM-5, above, measures gamma radiation from 0.1 mr/hr to 100 r/hr with alarm feature. Ranges to 500,000 r/hr are available. Recorder is driven by spring motor, rest of unit operates on dry batteries. Life is in excess of 200 hours recording continuously. *Jordan Electronic Mfg. Co., 119 E. Union St., Pasadena 1, Cal.*

H-V Selenium Rectifiers

Cartridge-type selenium rectifier, U45HP supplies 1.5 ma at 900 v d-c. Rectifier is half-wave, 2 in. long × ¼ in. o. d., with pigtail leads. Type U50HPF differs by supplying 1,000 volts, is ¼ in. shorter. *International Rectifier Corp., 1521 E. Grand Ave., El Segundo, Calif.*

Survey Meter

Model GS-3CD exceeds CVD-700 specifications in size, weight (4¾ lb), and ruggedness. Detects betas and gammas in three ranges 0–0.5, 0–5, and 0–50 mr/hr. Uses two flashlight D cells and three 45-volt miniature B batteries. *Nuclear Measurements Corp., 2460 Arlington Ave., Indianapolis 18, Indiana.*



Interlocking Shields

Magnetite concrete blocks shaped as shown above provide radiation shielding; ends are similarly shaped for no leakage. (This shape is also available in lead, 6 in. wide and 8 in. long.) High density means 40% less thickness required than for ordinary stone concrete when shielding Co^{60} gammas. Blocks are available in 8, 12, and 16-in. lengths. *Ray Proof Corp., 513 W. 54 St., New York 19, New York.*

Beta-Emitter Analyzer

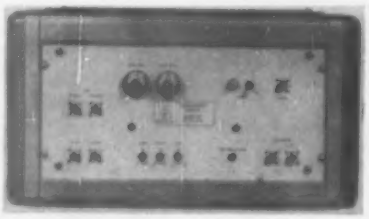
Model ISA isotope analyzer uses absorption and scattering of beta rays in high-Z materials to analyze 0.2×10^{-9}-curie beta emitters. Requires scaler with 0.25-volt input sensitivity and high-voltage supply. *Forro Scientific Co., 833 Lincoln Street, Evanston, Illinois.*

γ-Ray Spectrograph

Mark-20 spectrograph consists of scintillation probe and its power supply combined with a complete single-channel pulse-height analyzer and recorder. Nonoverloading amplifier has 1-μsec delay-line pulse shaper; differential analyzer has 0–5-volt window constant to within 0.1%. Precision (1%) linear counting-rate meter feeds *X-Y* recorder. Electrically reset scale-of-4,096 included for point checks. *Radiation Counter Laboratories, Inc., 5122 W. Grove St., Skokie, Illinois.*

Scintillation Probe

Type 653 scintillation head provides for scintillators of various sizes; interchangeable caps with thin end windows or lead collimators are available. Available scintillators include Pamelon activated plastic, Hornyak buttons, ZnS powder, and encapsulated NaI crystals in several sizes. Photomultiplier (EMI 6260) requires 1.2-kv supply; cathode follower requires 300 v at 10 ma and 6.3 v a-c at 0.3 amp. *Isotope Developments Ltd., Finsbury Pavement House, 120 Moorgate, London E. C. 2, England.*



Coincidence Circuit

Model DZ4, fast-slow coincidence circuit, above, developed from ORNL prototypes. Fast-channel resolving time is from 0.01 μsec to several μsec. Extreme flexibility of slow-channel input requirements permits use with multichannel analyzers. Accepts + or − pulses. *Detectolab, Inc., 6544 N. Sheridan Road, Chicago 26, Illinois.*

Counting-rate meter. Model 1620 analytical counting-rate meter reads directly in cpm, has six ranges to 100,000 cpm, built-in high-voltage supply. *Nuclear Instrument and Chemical Corp., 229 West Erie St., Chicago 10, Illinois.*

Prospecting counter. Mark IV Geiger counter weighs 3¾ lb and measures 3 × 4 × 7 in. over-all. Scales are 0–0.2 mr/hr and 10 and 100× that. Neon lamp and headphones give

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* 208 Tazewell Pike, Knoxville 18, Tenn.

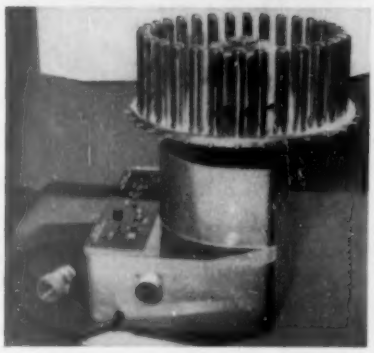
count-by-count readout of Geiger-counter output. *Menlo Research Laboratory, Menlo Park, California.*

Self-charging pocket dosimeter. German Ionometer measures dose to 200 mr, is 1 in. in diameter by 4½ in. long. Mechanical self-charger eliminates need for separate charger. *Nassau Distributing Co., 1733 Broadway, New York 19, N. Y.*

Dose meter. Three dosimeters (0.5, 5, and 50 r full scale) and model L-61 charger-reader give 2% accuracy from 120 kev to 1.4 Mev, with calibration provided for 20–130-kev region. *Landswerk Electrometer Co., 550 W. Garfield Ave., Glendale 4, California.*

Well-type scintillation detector. Model 810 counter has 1¾-in.-diameter 2-in.-high NaI(Tl) scintillator with ⅝-in.-diameter 1½-in.-deep well, DuMont 6292 photomultiplier, and unity gain amplifier. Model 810A has built-in linear amplifier with 0.25-volt output. *Atomic Instrument Co., 84 Massachusetts Ave., Cambridge 39, Mass.*

RADIOACTIVITY MATERIALS AND APPARATUS



Vial-Sample Changer

Model 35006-A, above, is an automatic sample changer for scintillation well counting of up to 32 liquid samples with activities down to 0.00001 μc. Operator presets positions to be read and number of times they are to be counted. All subsequent operations are automatic, including instructions to automatic scaler and printer. *Harper Engineering Co., 922 Dragon St., Dallas, Texas.*

Radioisotopes

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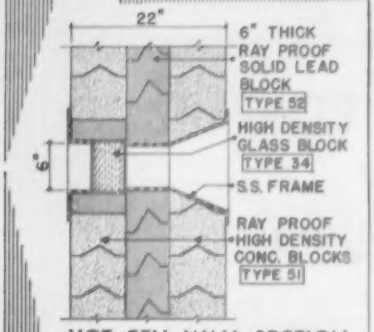

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Thin Films

Listed in table below are nickel and copper foils useful as absorbers and windows. Foils are liable to sporadic porosity but some have hole-free areas.

Electrodeposited Foils

	Nickel		*Copper*	
*Grade**	*Thickness (mils)*	*Area (in²)*	*Thickness (mils)*	*Area (in²)*
A	0.02–2	1–48	0.05–2	1–48
B	0.02–2	¼–16	0.12–2	¼–16
C	0.02–2	¼–4	0.12–2	¼–4
D	0.002–0.02	1–48	Not available	

* A: As made; B: Has central light-tight area; C: Light-tight over entire area; D: Too thin to handle, hence copper-backed; user dissolves copper.

Chromium Corporation of America, Attn. W. M. Sternfels, Waterbury 20, Connecticut.

Fastening Tool

Powered by a small gunpowder cartridge, Ramset tool can drive ½–6-in. steel studs into concrete. Shown above is application to lead lining; stud drove thorough ½-in. steel strap, ½-in. lead, and ⅜-in. steel tank wall. *Ramset Division, Olin-Mathesson Chemical Corp., 12,117 Berea Rd., Cleveland 11, Ohio.*

Wireless Microphone

Useful for laboratory communication and remote operations, Port-O-Vox pocket f-m transmitter is battery-operated, weighs 18 oz. total, operates at 27.51 Mc and has 100–600-ft range. Companion 24-lb receiver operates on 115v a-c. *Port-O-Vox Corp., 521 W. 43 St., New York 36, N. Y.*

ELECTRONIC INSTRUMENTS AND APPARATUS

Milli-Micromicroammeter

Model DC 151, above, operates on a-c, measures d-c currents from 3×10^{-15} to 10^{-7} amp in 15 ranges. Input voltage requirement is 0.25 mv full scale on all ranges. Accuracy is better than 5% on all except the lowest range, where it is 10%. *Scientific Specialties Corp., Snow and Union Streets, Boston 35, Mass.*

Impedance Bridge

Model 250-DA impedance bridge, above, measures resistance (0.1 milliohm to 12 megohms), capacitance (0.1 $\mu\mu$f to 1,200 mfd in 7 ranges), inductance (0.1 μh to 1,200 henrys in 7 ranges), dissipation factor (0.001 to 1.0), and storage factor (0.02 to 1,000). Networks available for operation at any fixed frequency between 100 and 10,000 cycles within 1%. *Electro-Measurements, Inc., 4312 E. Stark St., Portland 15, Oregon.*

Current-ratio meter. Panel meter indicates ratio of two direct currents between 2 and 50 ma. Movement uses two fixed coils surrounding small Alnico magnet attached to pivoted pointer. *Thomas A. Edison, Inc., Instrument Division, West Orange, New Jersey.*

Expanded-scale panel voltmeter. Use of thermal bridge permits expanded-scale indication of a-c voltages as low as 6.25 v with a span of 0.25 v,

or as high as 230 v with a 30-v span. Accuracy is 0.5%; frequency range is 50–2,000 cycles. *Arga Division, Beckman Instruments Inc., 220 Pasadena Ave., South Pasadena, California.*

INDUSTRY NOTES

▶**Keith H. Johnson** has replaced **Herbert N. Stewart,** former treasurer and general manager of **Detectolab, Inc.,** Chicago, Illinois.

▶**Ketay Instrument Corp.,** has purchased a majority stock interest in the **Vari-ohm Corp.,** Amityville, Long Island. Ketay will shortly consolidate with **Norden Laboratories Corp.,** to form the **Norden-Ketay Corp.**

▶**S. W. Brown** who participated in the design of the air-conditioning systems for the nuclear-powered submarines, Nautilus and Sea Wolf, has left the **Carrier Corp.** and established a consulting engineering firm at the Chrysler Building, New York City.

LITERATURE AVAILABLE

Mylar. Technical reports TR-1 and TR-2 describe Mylar, DuPont's polyester film, and adhesives for it, respectively. *Du Pont Film Department, Wilmington, Delaware.*

Transistors. Bulletin 1312 lists *pnp* junction transistors, gold-bonded germanium and silicon diodes. *Transitron Electronic Corp., Melrose 76, Massachusetts.*

Atom models. Apparatus News describes new atom models and other lab apparatus. *Arthur S. Lapine Co., 6001 S. Knox, Chicago, Ill.*

Pulse Generators. General catalog (4 p.), brochure 2120A (2 p.), and brochure 2140A (4 p.) on pulse instruments and generators, are available. *Electro-Pulse, Inc., 11811 Major St., Culver City, Cal.*

Temperature controller. Bulletin 104 describes adjustable bimetallic thermostat. *Burling Instrument Co., Inc., 16 River Rd., Chatham, N. J.*

Polyethylene. Catalog A954 lists many forms and products made of polyethylene. *Palo Laboratory Supplies, Inc., 81 Reade St., N. Y. 7, N. Y.*

Vacuum pumps. Catalog 750 (32 p.), listing available pumps, bulletin 755 (16 p.), describing their care, and a vacuum calculator are offered. *F. J. Stokes Machine Co., Phila. 20, Pa.*

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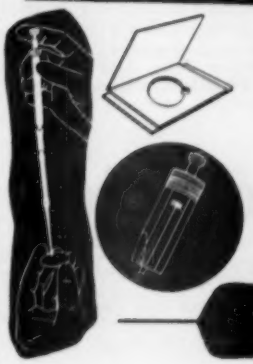

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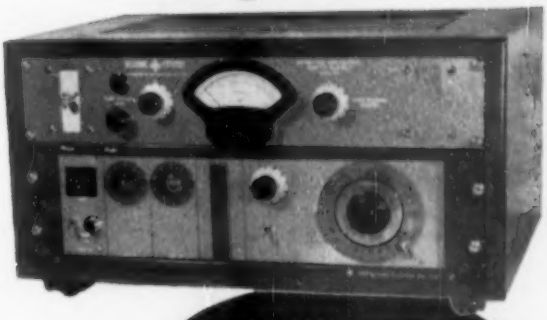


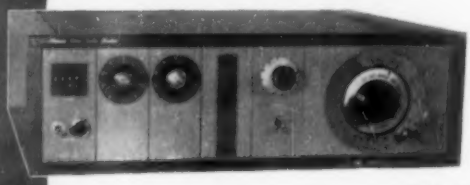
Model 1031 general purpose, 5 microsecond resolving time, scaler for radioactivity counting

3 MODELS FOR YOUR CHOICE

Model 1031 Pre-set Time Scaler (shown above), with built-in Regulated H. V. Supply, 500-2500 volts

Model 1035 Pre-set Time Scaler identical to Model 1031, except with 1000-5000v. Regulated H. V. Supply

Model 131 Pre-set Time Scaler (shown below) for use with separate H. V. Supply



MODEL 131

Atomic offers these additional new scalers for Geiger, Scintillation or Proportional counting . . . more economical instruments with the newest design features . . . may be used with standard Linear Amplifiers, Pulse Height Analyzers and suitable detection devices.

INPUT SENSITIVITY, 0.25v. negative, with adjustable stable discriminator
RESOLUTION, better than 5 microseconds
REGULATED HIGH VOLTAGE SUPPLY, (60 cycle type), 500-2500v. with coarse and fine controls (Model 1031)
SCALE FACTOR, scale of 1000 followed by 4-digit electro-mechanical register
CONTROL: Pre-Set Time or manual with elapsed time to 1 hour
RESET: Single switch resets both register and scaling stages
TIMER: Atomic's Model 960 Dual-Purpose Precision Timer, preset or elapsed time from 1 second up to 1 hour
DIRECT READING "VISUALIZED" COUNT
UNITIZED CONSTRUCTION, functional plug-in units provide simplified circuits of high reliability

Atomic's complete line of "research quality" instruments, including: Scalers, Amplifiers, H. V. Supplies, Analyzers, Scintillation equipment, etc., are described in the new General Catalog. Write for your "registered" copy.

Get complete information on Atomic's new Cold Cathode SCALERS—write today for Bulletin 1031-1.

For full details on Atomic's Standard 10-10 Series Scalers, please request Bulletin 1010-1.

Watch for more new ATOMIC precision instruments for nuclear research.

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● **REFERENCE DATA:** Write for Bulletin 14-1, "Automatic Instrumentation to Accelerate Research."

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